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DISEASES AND INSECTS

in British Columbia Forest Seedling Nurseries

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Diseases and Insects in British Columbia Forest Seedling Nurseries

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Abstract

This publication was prepared to assist nursery personnel in identifying and managing diseases and insects in British Columbia forest seedling nurseries. The first section of this handbook contains information on pest prevention and diagnosis, plus general information and references on chemical control. This is followed by sections on: (i) diseases affecting seeds, roots or root collar area, (ii) shoot diseases, (iii) insects affecting roots or root collar area, and (iv) insects and mites affecting shoots. Each of the latter four sections contains several chapters on specific pests. Also included are tables of minor diseases and insects and a glossary of pest related terms.

Résumé

Ce manuel a été préparé pour aider le personnel des pépinières à reconnaître et contrôler les maladies et les insectes dans les pépinières de plants forestiers en Colombie-Britannique. La première section de ce manuel est consacrée à la prévention et au diagnostic des ravageurs. Elle donne également des instructions générales et des références sur la lutte chimique. Dans les quatre sections qui suivent, il est question: (i) des maladies attaquant les graines, les racines; et le collet, (ii) des maladies affectant les pousses, (iii) des insectes attaquant les racines et le collet, et (iv) des insectes et des acariens des pousses. Dans chacune de ces quatre sections, on trouve plusieurs chapitres traitant de ravageurs particuliers. Ce manuel contient également deux tableaux des ravageurs de moindre importance et un glossaire.

Preface

Sustained and improved production of forest seedling crops depends in part upon effective management of nursery pests. Early and correct identification of pests is the first vital step in a nursery pest management program.

This is the second edition of this very popular handbook which was first published in 1980. Since then, production of seedlings in containers has continued to account for an ever-increasing amount of the annual seedling production in British Columbia. As a result of this and other factors, the importance of certain pests has changed. Also, new information has been gained about the biology and management of nursery pests; and other important diseases and insects have appeared locally for the first time.

The purpose of the new handbook, like that of its predecessor, is to provide nursery managers in British Columbia with information on nursery pest identification and management. It contains host and damage information, descriptions of critical life history stages, and, where applicable, preventive cultural control practices. Recommendations for chemical controls are not included because prescriptions for these change rapidly. If information on pesticides is required the publications listed in the section entitled "Chemical Control" should be consulted.

We anticipate that integrated pest management, a pest management system that uses all suitable techniques and methods (e.g., cultural practices, monitoring programs, and chemical controls) to reduce pest populations, will become increasingly prominent in nursery pest management. This handbook will provide nursery managers with an improved capability for initial identification of the most common and regularly recurring nursery pests.

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Introduction

Pests directly affect the quantity and quality of forest nursery seedlings and can indirectly cause losses by disrupting reforestation plans or reducing survival of outplanted stock. The movement of infested stock can disseminate pests to new areas. Since control of nursery pests may be based on pesticide usage, pest outbreaks may lead to environmental contamination.

In recent years, forest nursery managers have become increasingly aware of the significance of pest losses in British Columbia forest nurseries. This handbook was prepared to help in the identification and management of important diseases and insects in local nurseries. It is formatted so that the user can tentatively identify disease and insect problems by referring to the flow chart keys and then consulting the specific chapters on each pest, or group of pests, for more information on hosts and damage, life history, and management.

In general, the length of each chapter is governed by the importance and amount of information available on a particular problem. If in-depth information on a problem was lacking, we omitted certain headings (e.g.,"Life History") in some chapters. Where warranted, we have included a general life history diagram for the pest.

We have attempted to provide sufficient information, to allow the user to recognize specific pests and to follow the logic of the management recommendations. Management practices that emphasize procedures other than the use of pesticides-, e.g., prevention of pest problems and manipulation of cultural practices-are also given. These include:

For nursery site selection factors

1. Selecting a site with an adequate supply of water that is free of toxic chemicals, pH problems, and pests.
2. Selecting a site that is unaffected by adverse weather such as frost pockets and severe winds, and, in the case of bareroot nurseries, by additional factors such as flooding and frost heaving.
3. Avoiding sites with potential or known high levels of pests in the surrounding area (e.g., nearby forest stands with a high incidence of pine infested by western gall rust or nearby alfalfa fields which often harbor the Lygus bug).
4. For bareroot nurseries, selecting a sandy, well-drained, moderately acid soil. Such soils generally favor seed germination, seedling emergence, and growth, while hindering pest survival and proliferation. These soils are also easier to rid of pests.

For cultural practices

1. Preventing exposure of seedlings to factors such as frost damage, nutrient deficiencies, and toxic chemicals, which predispose them to pest invasion or injury, or both. Keeping seedlings healthy deters pest attack and losses.
2. Regulating environmental factors such as watering, aeration, and lighting, so that they hinder pest development or survival while not adversely affecting seedlings.
3. Using sanitation and pest exclusion practices such as: (i) restricting or preventing movement of pest-infested stock or equipment among nurseries, (ii) removing or reducing weeds, and placing grass and ornamental plantings well away from nursery areas, (all of these can harbor insects and pathogens), (iii) removing infested seedlings or those that are potential sources for pest build up, (iv) periodically checking water supplies for pathogens, (v) regularly checking soil amendments or container mix components for pests, (vi) ridding the area around the nursery of diseased trees and alternative hosts (e.g., for rusts), and (vii) where practical, producing stock in insect-proof greenhouses.
4. Establishing survey and monitoring programs (e.g., pheromone traps and yellow, sticky cards) for potential or incipient insect problems.
5. Bare fallowing soils or using crop rotation schemes unfavorable to pests.
6. Growing susceptible hosts outside pest-infested areas (e.g., where feasible, growing *Abies* species outside the balsam woolly aphid quarantine area).
7. Planting resistant seedling species, provenances, or age classes in infested areas (e.g., putting transplants in areas prone to damping-off).
8. Using pesticides to prevent rather than to eradicate pest problems.

Infectious and Noninfectious Diseases

Plant diseases can be classified according to the plant part they affect, the type of symptoms they cause, the type of pathogen involved, or the fact that they are infectious or noninfectious. Infectious diseases are caused by pathogens, mainly fungi, and can spread among plants. Prerequisites for the development of an infectious disease include: (i) a susceptible host, (ii) presence of a pathogen, and (iii) a favorable environment. Together, these factors form the pathologist's "Disease Triangle" (Figure 1). Sufficient time for the disease process to develop is also needed.

Of importance to nursery managers is the fact that cultural practices can significantly affect all of these factors and prevent completion of the triangle. For example, although the spores of many seedling pathogens are ubiquitous, good sanitation practices (e.g., cleaning up piles of culled seedlings) will decrease spore numbers in the nursery. Sometimes it is possible to exclude a pathogen from the nursery. Such is the case when pines with western gall rust are removed from within and near the nursery to prevent inoculum from reaching seedlings.

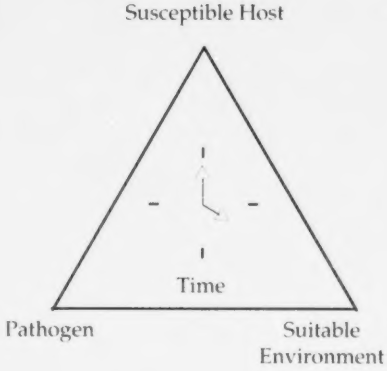


Figure 1. Disease triangle showing prerequisites for disease development.

Cultural practices can also affect seedling susceptibility to disease. For example, applying excess fertilizer can kill foliage and lead to gray mould establishment, first on dead or senescent tissues and then on living host parts; applying nitrogenous fertilizers to germinants can increase their general susceptibility to disease; and watering seedlings late in the day can result in foliage remaining wet overnight, which favors pathogens that require high humidity or free water for infection. Thus, it is the job of the nursery manager to use practices which either prevent diseases or inhibit their development or spread, or both. In the long run, this approach is usually more cost effective than is applying pesticides. Indeed, even when pesticides are used, their efficacy often depends upon their being used in conjunction with the appropriate cultural practices.

Although only infectious diseases are detailed in this handbook, the nursery manager needs to have an understanding of noninfectious (abiotic) diseases – often called "physiological disorders". Included here are problems caused by inclement weather, unfavorable soil conditions, and injuries from toxic chemicals, such as herbicides (Figures 2-8). Pathogens are not involved, and noninfectious problems are not contagious.

Noninfectious diseases directly affect seedling quantity and quality, but more often their indirect effect of predisposing seedlings to infectious diseases is more important. For example, frost or fertilizer-damaged seedlings are more prone to storage moulds and often suffer gray mould losses because the pathogen, *Botrytis cinerea*, builds up on the killed foliage and spreads to healthy seedlings. Pre-emergence damping-off losses are often higher in compacted soil or growing medium because of hindered germinant emergence. In addition, soil pH may be selectively favorable or unfavorable for pathogens.

Some of the main characteristics distinguishing infectious and noninfectious diseases

CHARACTERISTICS	INFECTIOUS	NONINFECTIOUS
Symptoms (host appearance)		
Within nursery	Usually limits not defined; not corresponding to cultural practices or environmental factors	Usually well demarcated within a specific section or seedbeds; often corresponding to cultural practices or environmental factors.
On affected seedlings	Usually not oriented to direction of sun or wind; often spreading to other seedlings.	Usually clearly delineated, e.g., specific sections of needles killed by fertilizer burn, or damage oriented from the direction of the sun or wind; most seedlings equally affected; no spreading to other seedlings.
Type	Tissues often decayed or swollen.	Tissues usually desiccated, physically damaged, chlorotic, etc., but not initially decayed.
Development rate	Usually develop slowly, uneven development rate, e.g., some seedlings dead while others are dying and others are unaffected.	Usually develop quickly, e.g., after fertilizer or herbicide application or inclement weather. Symptoms usually all develop to the same stage.
Signs (evidence of pathogen)	Pathogen, e.g., fungus mycelium or spore-producing structures, often present.	No evidence of pathogen.
Hosts	Often restricted as to host and host age.	Can affect numerous hosts of various ages.

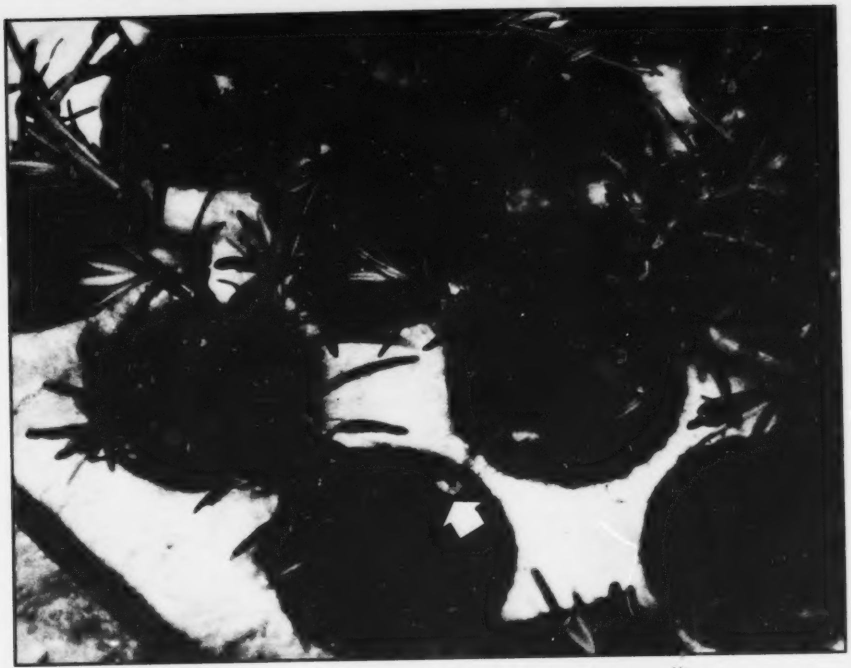


Figure 2. Fertilizer burn on foliage of western hemlock container seedlings. Note fertilizer pellets (arrow).

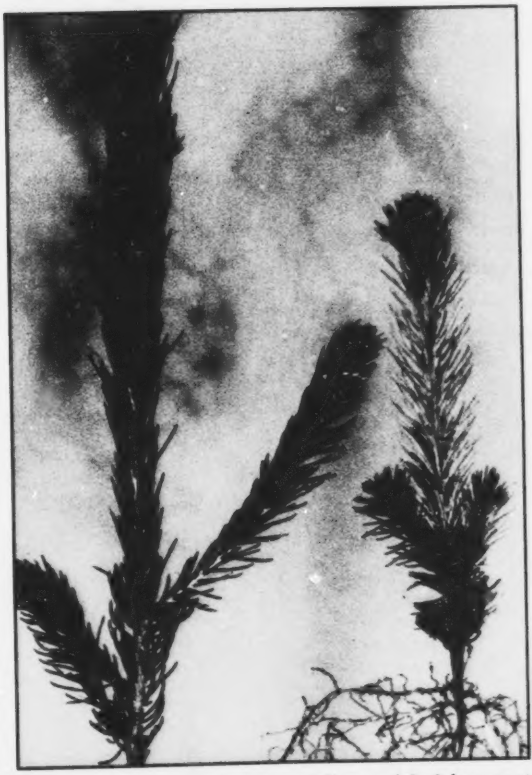


Figure 3. Fertilizer burn on foliage of 2+0 bareroot white spruce.

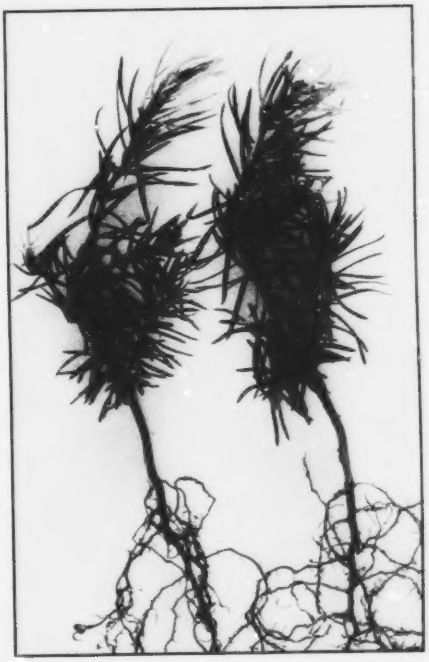


Figure 4. Frost damage on 2+0 Douglas-fir.

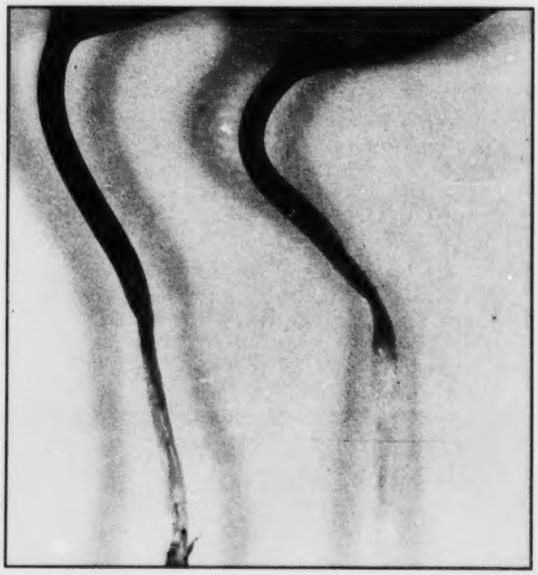


Figure 5. Sunscald damage (constricted stem) on Douglas-fir germinants.

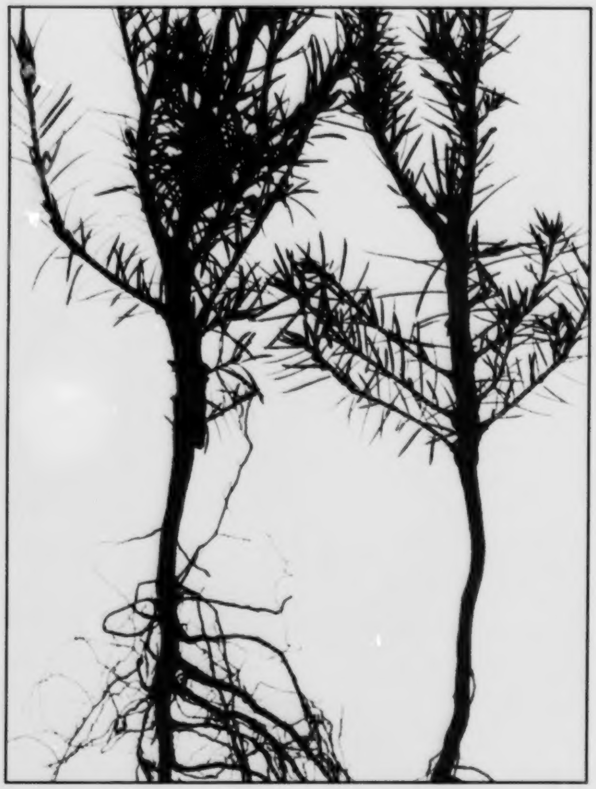


Figure 6. Effects on 2+0 bareroot Douglas-fir of solvent used to bond plastic irrigation pipe.

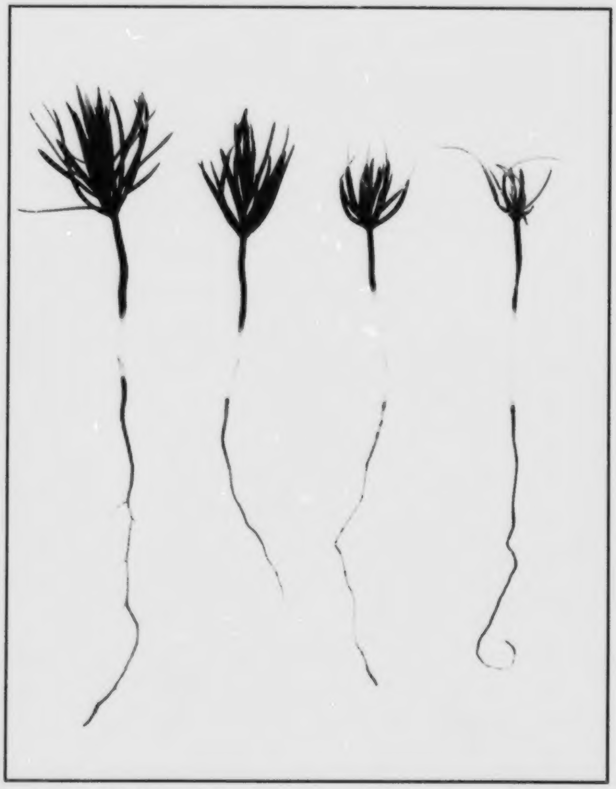


Figure 7. Herbicide damage (two right-hand seedlings) on Douglas-fir.

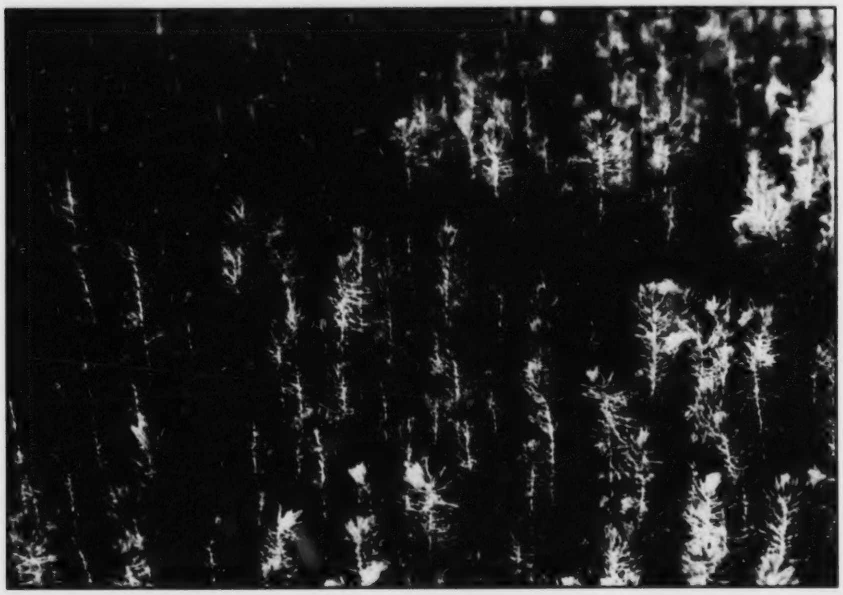


Figure 8. Drought damage on container-grown spruce.

Selected References

Agrios, G.N. 1988. Plant pathology. 3rd ed. Academic Press, Inc., New York, N.Y.

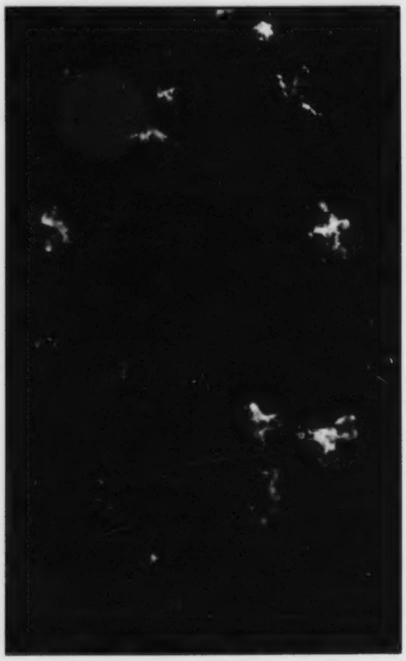


Figure 9. Mycorrhizae on 2+0 container-grown lodgepole pine. Note dichotomously-branched, short roots.

Mycorrhizae

Besides pathogenic fungi, there also exists a group of fungi which infect conifer seedling roots to form symbiotic "fungus roots" or mycorrhizae. These fungi, which include some mushroom and puffball-producing basidiomycetes, cause seedling feeder roots to swell and become forked (Figure 9), but do not cause root disease. Instead, most mycorrhizal fungi are considered to be beneficial to their hosts, primarily by enhancing nutrient and water uptake. An exception occurs when the mycorrhizal fungus *Thelephora terrestris* (see p. 49) overgrows seedling shoots, smothering them. Mycorrhizae of forest seedlings form tightly interwoven layers of hyphae between or around the outside of the cortical cells of feeder roots, and so are specifically termed "ectomycorrhizae" (i.e., they do not enter root cells). These mycorrhizae are brown, white, yellow, or black, depending on the color of the fungus infecting the root. Visually, ectomycorrhizae are distinguished from pathogenic and secondary fungi by their occurrence, on the roots of seedlings, without accompanying signs or symptoms of decay. Nursery personnel will likely come to recognize any mycorrhizae common to their area.

Insects and Mites

Insects have been of less concern than diseases in British Columbia's conifer seedling nurseries. Nevertheless, these nurseries have a unique complex of insect pests because young, succulent seedlings can host insects that may or may not be specific to conifers. For example, the *Lygus* bug, normally a pest of agricultural crops, may come into nurseries from neighboring fields. Western spruce budworm, usually associated with defoliation of mature conifers, may be blown into nursery areas from adjacent forest stands.

Given the small size of seedlings and the density at which they are grown, even a low number of insects can cause severe damage and spread rapidly. Individual cutworms can destroy several seedlings in a few hours. Furthermore, infested stock can disseminate insects to new areas such as planting sites, where stock survival can be reduced. This kind of movement is of particular concern with introduced pests.

Notwithstanding the emphasis on non-chemical pest management in this handbook, it is recognized that insecticide applications are often necessary to prevent severe damage to a seedling crop.

For many insect pest management programs, monitoring techniques - including pheromone traps - have been established. Also, several of the procedures listed in the introduction of this book can be used to prevent insect-caused losses. The insects covered here are those that occur with some degree of regularity in British Columbia forest seedling nurseries.

Chemical Control

Implementing management practices that emphasize prevention and cultural controls greatly reduces the necessity for using pesticides. Nonetheless, anyone who applies pesticides must be thoroughly familiar with the biology of the pest and host, as well as with application techniques, safety, and the regulations that govern the use of pesticides. These latter topics are covered in the most recent nursery pest control handout from Extension Services of the British Columbia Ministry of Forests, and in the most recent editions of:

Forest Pesticide Handbook of British Columbia. 1985. Council of Forest Industries and B. C. Ministry of Forests, Vancouver, B.C.

Handbook for Pesticide Applicators and Dispensers. 1987. B.C. Ministry of the Environment, Pesticide Control Branch, Victoria, B.C.

Using This Handbook for Pest Diagnosis

The use of criteria such as type of damage, plant species affected, and season of symptom appearance often allows both pest-caused and noninfectious problems to be identified at the nursery. To aid in identification, we have included flow chart keys and illustrations for seed, root or root collar diseases (p. 8), shoot diseases (p. 10 and 12), insects affecting roots or root collar areas (p. 14), and insects and mites affecting shoots (p. 16 and 18).

To diagnose pest problems, take the following steps:

- Decide if a problem is disease- or insect-caused; use the headings for the keys on pages 8 through 18.
- Examine the pictures on the accompanying pages for the symptom or stage of the pest that you have tentatively identified, then consult the text chapter for details on the pest's biology and management.
- If you cannot identify the problem by using the information in the main body of the bulletin, consult the table of minor diseases on p. 50 and table of minor insects on p. 79.
- If you are still in doubt about the identity of a pest, consult a plant pathologist or an entomologist.

Flow Chart Keys

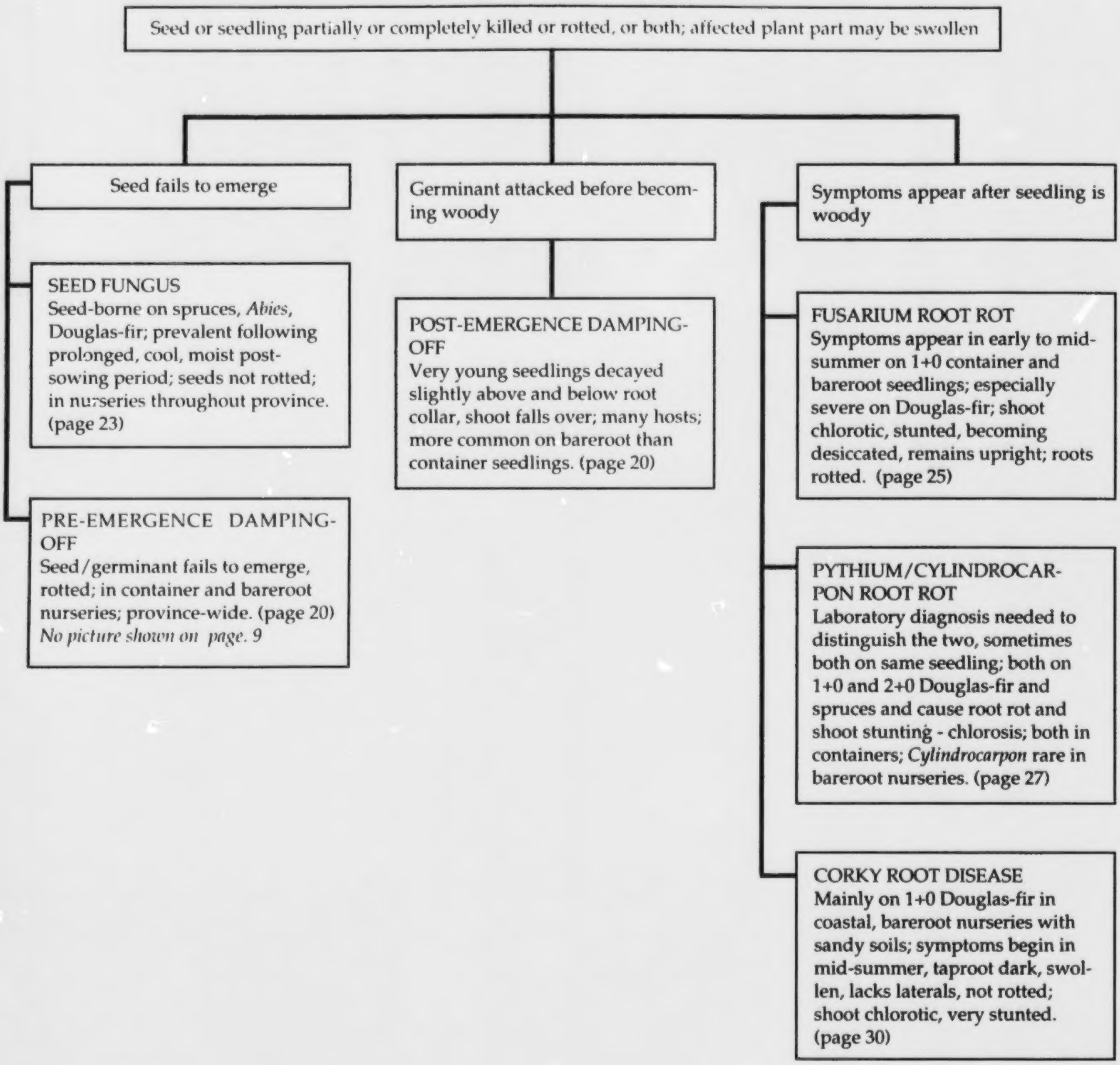
Flow chart key for identifying diseases affecting seeds, roots, or root collar area ...... p. 8

Flow chart keys for identifying diseases affecting shoots .... p. 10 & 12

Flow chart keys for identifying insects affecting seeds, roots, or root collar area .... p. 14

Flow chart keys for identifying insects and mites affecting shoots .... p. 16 &18

DISEASES AFFECTING SEEDS, ROOTS OR ROOT COLLAR AREA



- Seed or seedling partially or completely killed or rotted, or both; affected plant part may be swollen
  - Seed fails to emerge
    - SEED FUNGUS
      Seed-borne on spruces, *Abies*, Douglas-fir; prevalent following prolonged, cool, moist post-sowing period; seeds not rotted; in nurseries throughout province. (page 23)
    - PRE-EMERGENCE DAMPING-OFF
      Seed/germinant fails to emerge, rotted; in container and bareroot nurseries; province-wide. (page 20) *No picture shown on page. 9*
  - Germinant attacked before becoming woody
    - POST-EMERGENCE DAMPING-OFF
      Very young seedlings decayed slightly above and below root collar, shoot falls over; many hosts; more common on bareroot than container seedlings. (page 20)
  - Symptoms appear after seedling is woody
    - **FUSARIUM ROOT ROT**
      Symptoms appear in early to mid-summer on 1+0 container and bareroot seedlings; especially severe on Douglas-fir; shoot chlorotic, stunted, becoming desiccated, remains upright; roots rotted. (page 25)
    - **PYTHIUM/CYLINDROCARPON ROOT ROT**
      Laboratory diagnosis needed to distinguish the two, sometimes both on same seedling; both on 1+0 and 2+0 Douglas-fir and spruces and cause root rot and shoot stunting - chlorosis; both in containers; *Cylindrocarpon* rare in bareroot nurseries. (page 27)
    - **CORKY ROOT DISEASE**
      Mainly on 1+0 Douglas-fir in coastal, bareroot nurseries with sandy soils; symptoms begin in mid-summer, taproot dark, swollen, lacks laterals, not rotted; shoot chlorotic, very stunted. (page 30)

Seed fungus

Fusarium root rot

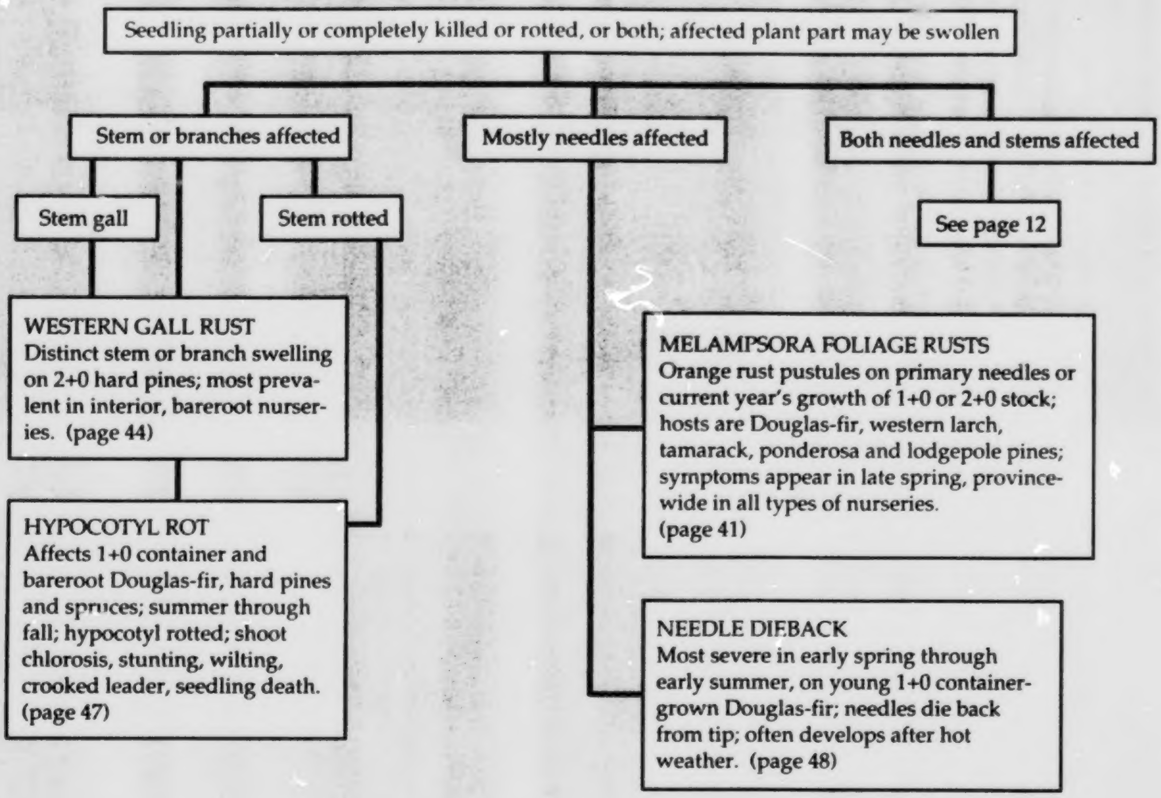
Cylindrocarpon root rot

Post-emergence damping off

Pythium root rot

Corky root disease

DISEASES AFFECTING SHOOTS



Seedling partially or completely killed or rotted, or both; affected plant part may be swollen

Stem or branches affected

Stem gall

Stem rotted

WESTERN GALL RUST
Distinct stem or branch swelling on 2+0 hard pines; most prevalent in interior, bareroot nurseries. (page 44)

HYPOCOTYL ROT
Affects 1+0 container and bareroot Douglas-fir, hard pines and spruces; summer through fall; hypocotyl rotted; shoot chlorosis, stunting, wilting, crooked leader, seedling death. (page 47)

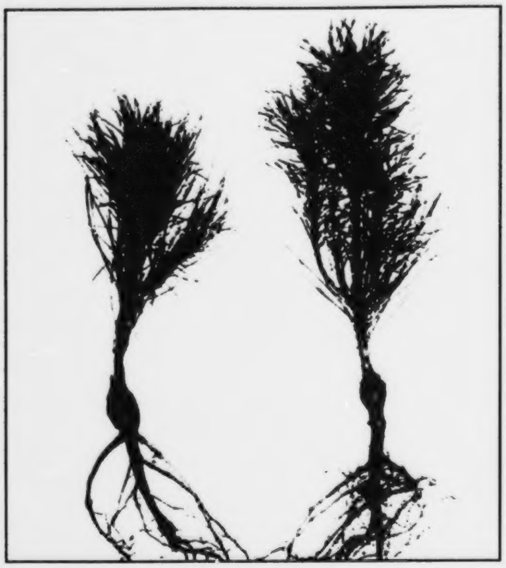
Mostly needles affected

MELAMPSORA FOLIAGE RUSTS
Orange rust pustules on primary needles or current year's growth of 1+0 or 2+0 stock; hosts are Douglas-fir, western larch, tamarack, ponderosa and lodgepole pines; symptoms appear in late spring, province-wide in all types of nurseries. (page 41)

NEEDLE DIEBACK
Most severe in early spring through early summer, on young 1+0 container-grown Douglas-fir; needles die back from tip; often develops after hot weather. (page 48)

Both needles and stems affected

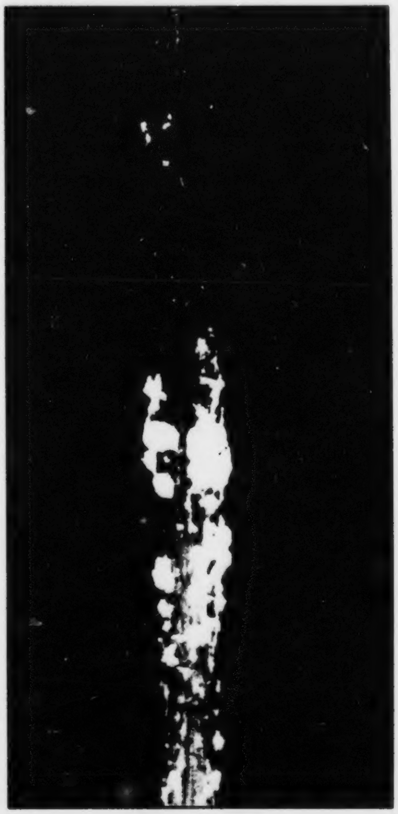
See page 12



Western gall rust

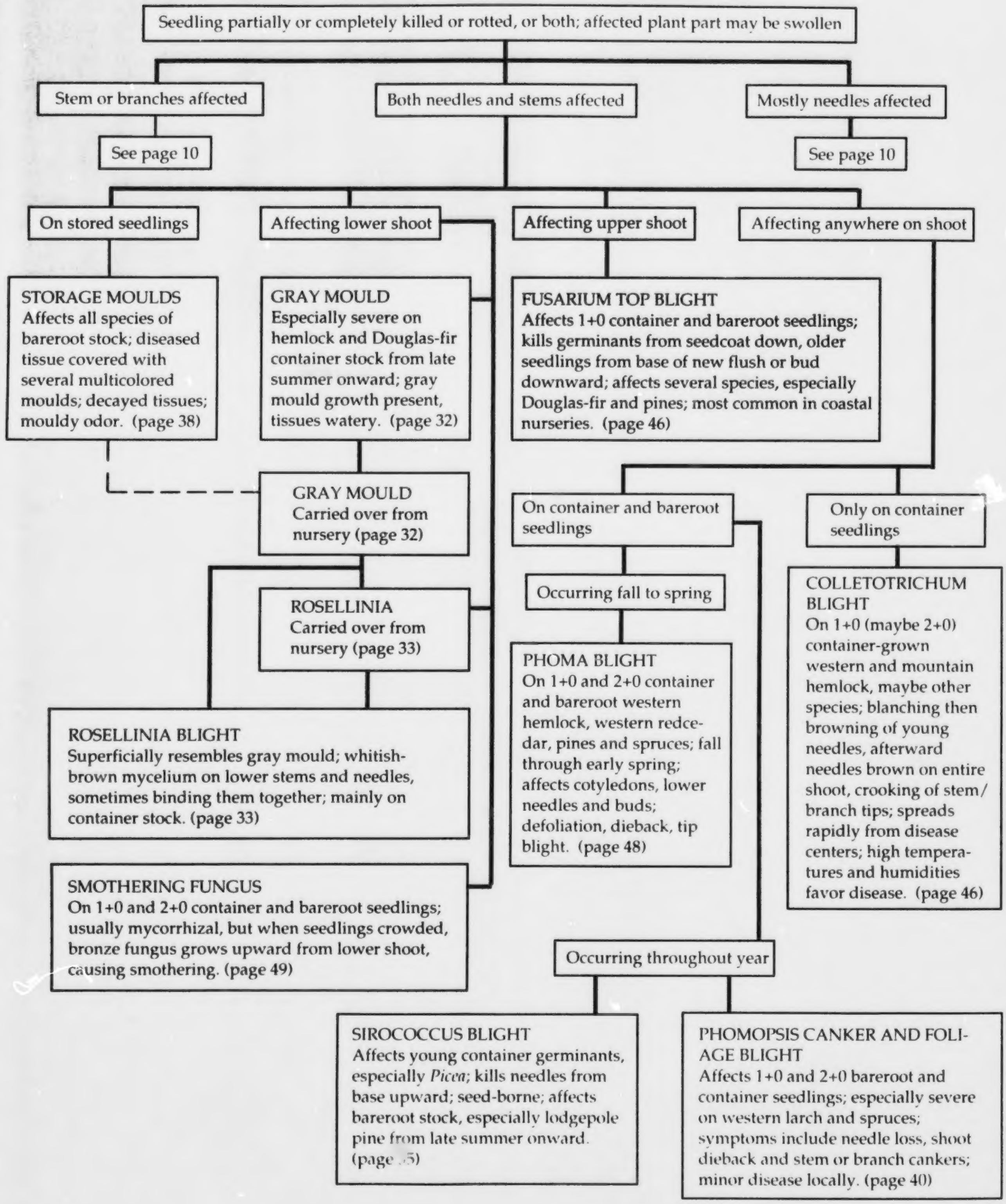
Needle dieback

Melampsora foliage rusts



Hypocotyl rot

DISEASES AFFECTING SHOOTS (continued)



Seedling partially or completely killed or rotted, or both; affected plant part may be swollen

Stem or branches affected

See page 10

Both needles and stems affected

Mostly needles affected

See page 10

On stored seedlings

STORAGE MOULDS
Affects all species of bareroot stock; diseased tissue covered with several multicolored moulds; decayed tissues; mouldy odor. (page 38)

Affecting lower shoot

GRAY MOULD
Especially severe on hemlock and Douglas-fir container stock from late summer onward; gray mould growth present, tissues watery. (page 32)

GRAY MOULD
Carried over from nursery (page 32)

ROSELLINIA
Carried over from nursery (page 33)

ROSELLINIA BLIGHT
Superficially resembles gray mould; whitish-brown mycelium on lower stems and needles, sometimes binding them together; mainly on container stock. (page 33)

SMOTHERING FUNGUS
On 1+0 and 2+0 container and bareroot seedlings; usually mycorrhizal, but when seedlings crowded, bronze fungus grows upward from lower shoot, causing smothering. (page 49)

Affecting upper shoot

FUSARIUM TOP BLIGHT
Affects 1+0 container and bareroot seedlings; kills germinants from seedcoat down, older seedlings from base of new flush or bud downward; affects several species, especially Douglas-fir and pines; most common in coastal nurseries. (page 46)

Affecting anywhere on shoot

On container and bareroot seedlings

Occurring fall to spring

PHOMA BLIGHT
On 1+0 and 2+0 container and bareroot western hemlock, western redcedar, pines and spruces; fall through early spring; affects cotyledons, lower needles and buds; defoliation, dieback, tip blight. (page 48)

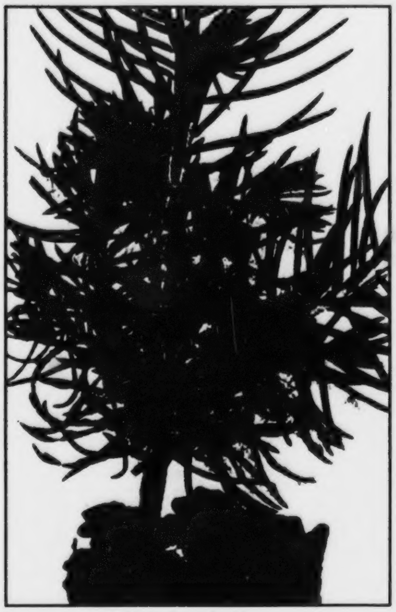
Occurring throughout year

SIROCOCCUS BLIGHT
Affects young container germinants, especially *Picea*; kills needles from base upward; seed-borne; affects bareroot stock, especially lodgepole pine from late summer onward. (page [illegible]5)

PHOMOPSIS CANKER AND FOLIAGE BLIGHT
Affects 1+0 and 2+0 bareroot and container seedlings; especially severe on western larch and spruces; symptoms include needle loss, shoot dieback and stem or branch cankers; minor disease locally. (page 40)

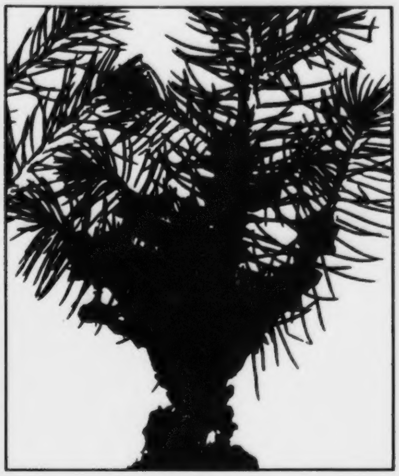
Only on container seedlings

COLLETOTRICHUM BLIGHT
On 1+0 (maybe 2+0) container-grown western and mountain hemlock, maybe other species; blanching then browning of young needles, afterward needles brown on entire shoot, crooking of stem/branch tips; spreads rapidly from disease centers; high temperatures and humidities favor disease. (page 46)

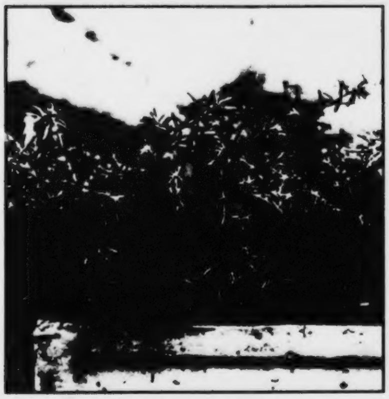


Gray mould

Rosellinia blight



Smothering fungus



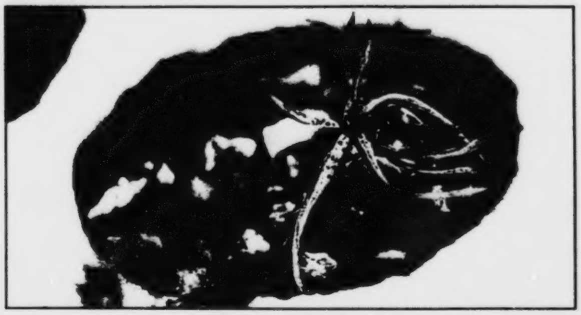
Colletotrichum blight

Phoma blight

Storage moulds

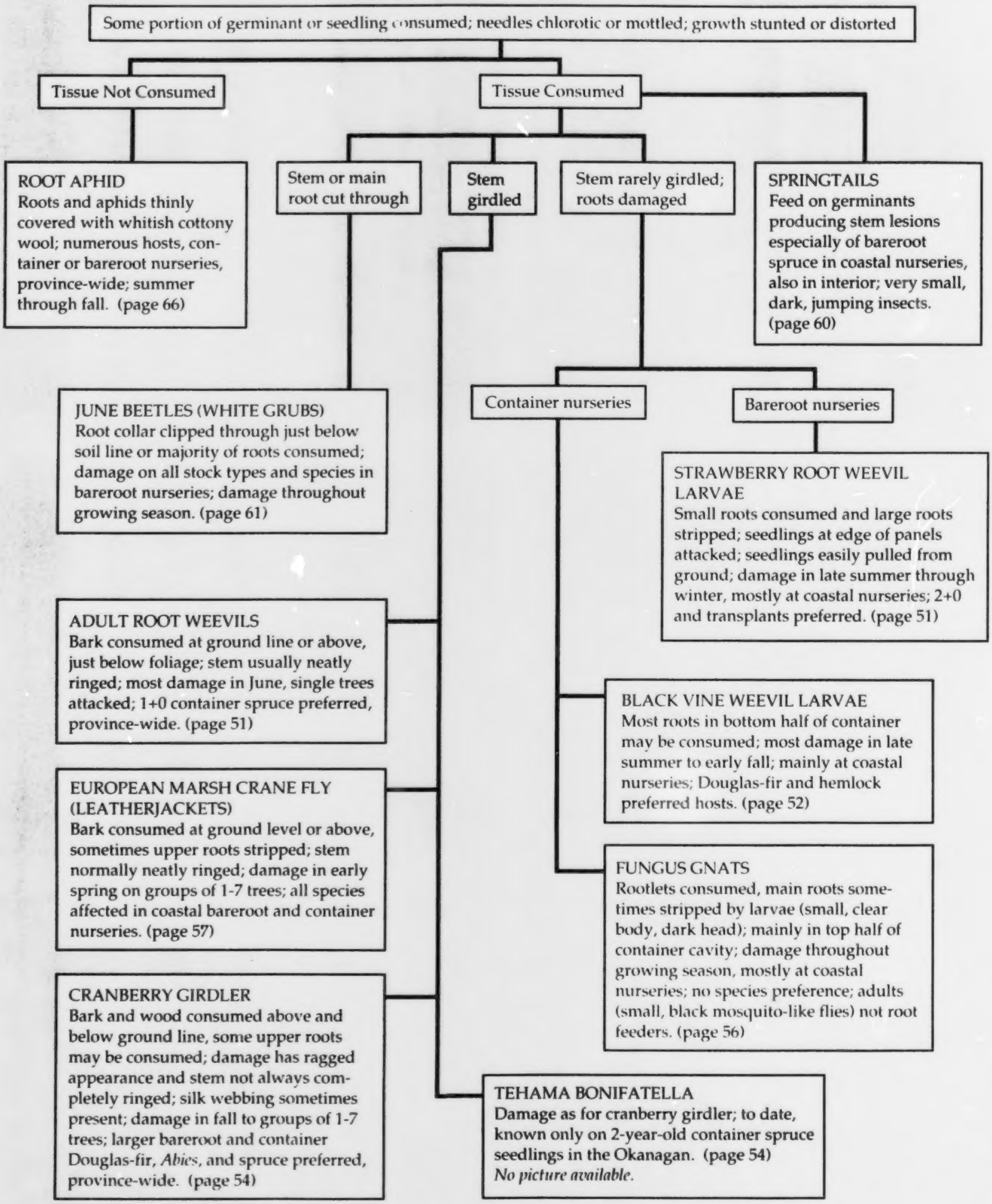
Phomopsis canker and foliage blight

Fusarium top blight



Sirococcus blight

INSECTS AFFECTING ROOTS OR ROOT COLLAR AREA



Some portion of germinant or seedling consumed; needles chlorotic or mottled; growth stunted or distorted

Tissue Not Consumed

ROOT APHID
Roots and aphids thinly covered with whitish cottony wool; numerous hosts, container or bareroot nurseries, province-wide; summer through fall. (page 66)

Tissue Consumed

Stem or main root cut through

JUNE BEETLES (WHITE GRUBS)
Root collar clipped through just below soil line or majority of roots consumed; damage on all stock types and species in bareroot nurseries; damage throughout growing season. (page 61)

Stem girdled

ADULT ROOT WEEVILS
Bark consumed at ground line or above, just below foliage; stem usually neatly ringed; most damage in June, single trees attacked; 1+0 container spruce preferred, province-wide. (page 51)

EUROPEAN MARSH CRANE FLY (LEATHERJACKETS)
Bark consumed at ground level or above, sometimes upper roots stripped; stem normally neatly ringed; damage in early spring on groups of 1-7 trees; all species affected in coastal bareroot and container nurseries. (page 57)

CRANBERRY GIRDLER
Bark and wood consumed above and below ground line, some upper roots may be consumed; damage has ragged appearance and stem not always completely ringed; silk webbing sometimes present; damage in fall to groups of 1-7 trees; larger bareroot and container Douglas-fir, *Abies*, and spruce preferred, province-wide. (page 54)

TEHAMA BONIFATELLA
Damage as for cranberry girdler; to date, known only on 2-year-old container spruce seedlings in the Okanagan. (page 54)
No picture available.

Stem rarely girdled; roots damaged

Container nurseries

BLACK VINE WEEVIL LARVAE
Most roots in bottom half of container may be consumed; most damage in late summer to early fall; mainly at coastal nurseries; Douglas-fir and hemlock preferred hosts. (page 52)

FUNGUS GNATS
Rootlets consumed, main roots sometimes stripped by larvae (small, clear body, dark head); mainly in top half of container cavity; damage throughout growing season, mostly at coastal nurseries; no species preference; adults (small, black mosquito-like flies) not root feeders. (page 56)

Bareroot nurseries

STRAWBERRY ROOT WEEVIL LARVAE
Small roots consumed and large roots stripped; seedlings at edge of panels attacked; seedlings easily pulled from ground; damage in late summer through winter, mostly at coastal nurseries; 2+0 and transplants preferred. (page 51)

SPRINGTAILS
Feed on germinants producing stem lesions especially of bareroot spruce in coastal nurseries, also in interior; very small, dark, jumping insects. (page 60)

Cranberry girdler

Root aphid

Root Weevils

Springtails

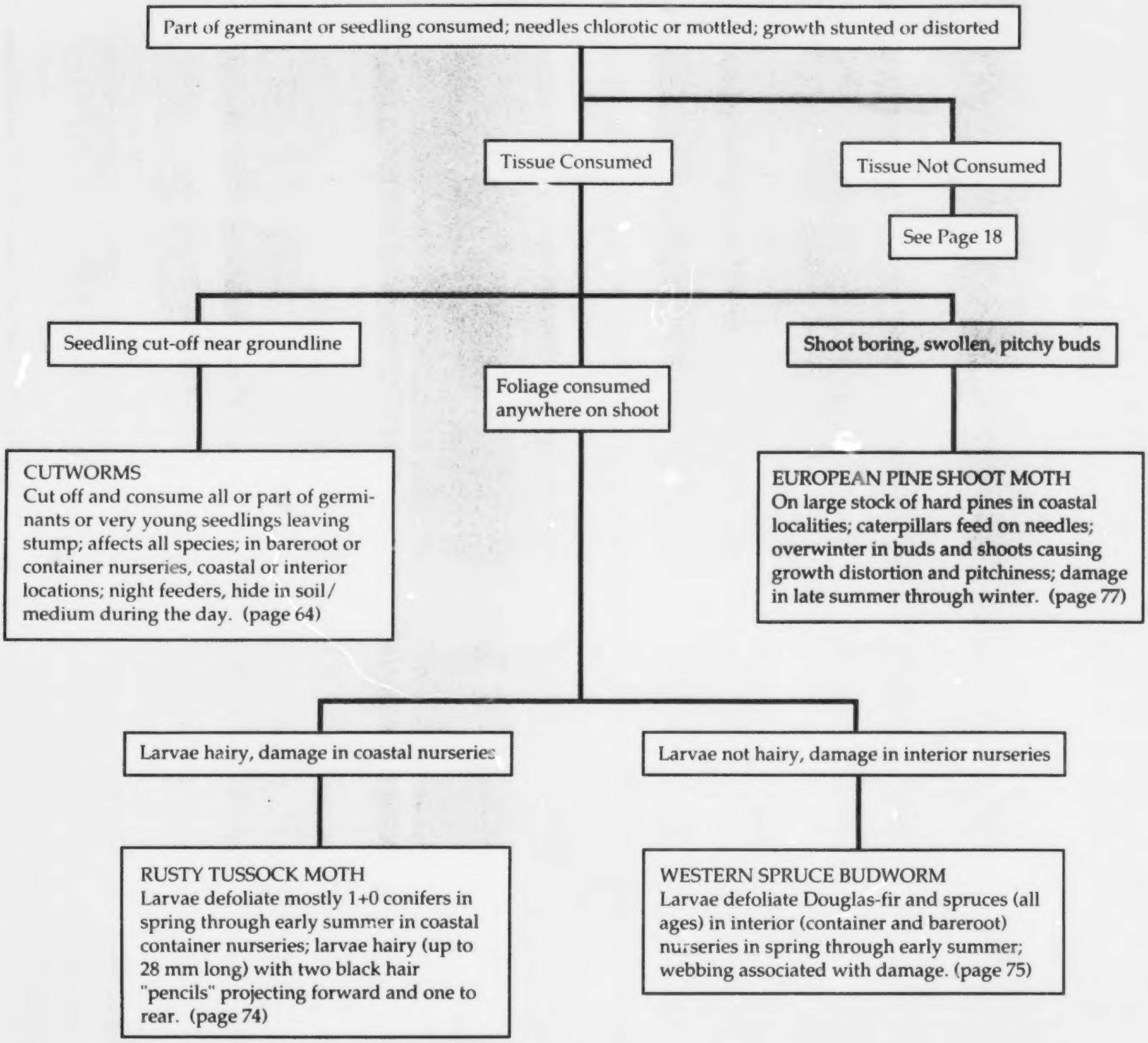
European marsh crane fly (leatherjackets)

Fungus gnats

June beetles (white grub)

Note: See Figure 66 for picture of black vine weevil and strawberry root weevil larvae.

INSECTS AND MITES AFFECTING SHOOTS



Part of germinant or seedling consumed; needles chlorotic or mottled; growth stunted or distorted

Tissue Consumed

Tissue Not Consumed

See Page 18

Seedling cut-off near groundline

Foliage consumed anywhere on shoot

Shoot boring, swollen, pitchy buds

CUTWORMS
Cut off and consume all or part of germinants or very young seedlings leaving stump; affects all species; in bareroot or container nurseries, coastal or interior locations; night feeders, hide in soil/medium during the day. (page 64)

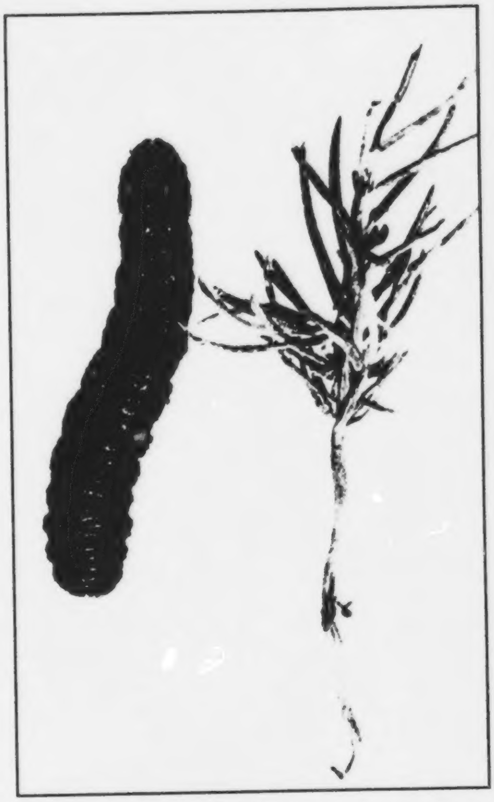
EUROPEAN PINE SHOOT MOTH
On large stock of hard pines in coastal localities; caterpillars feed on needles; overwinter in buds and shoots causing growth distortion and pitchiness; damage in late summer through winter. (page 77)

Larvae hairy, damage in coastal nurseries

Larvae not hairy, damage in interior nurseries

RUSTY TUSSOCK MOTH
Larvae defoliate mostly 1+0 conifers in spring through early summer in coastal container nurseries; larvae hairy (up to 28 mm long) with two black hair "pencils" projecting forward and one to rear. (page 74)

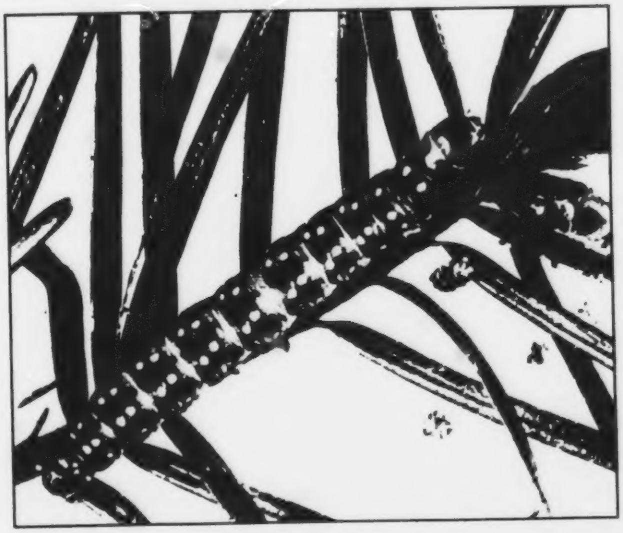
WESTERN SPRUCE BUDWORM
Larvae defoliate Douglas-fir and spruces (all ages) in interior (container and bareroot) nurseries in spring through early summer; webbing associated with damage. (page 75)



Cutworms

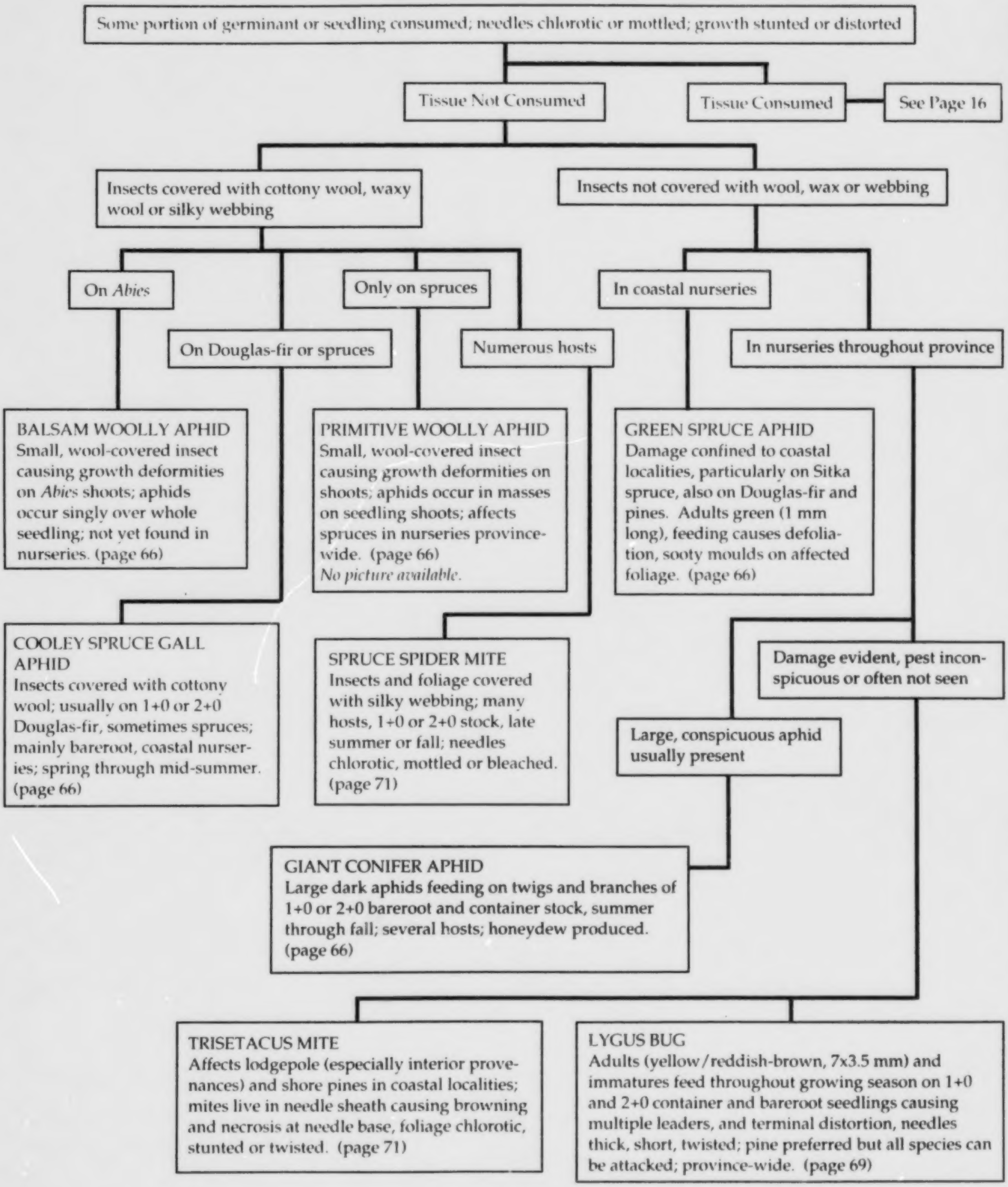
Rusty tussock moth (larva)

European pine shoot moth



Western spruce budworm

INSECTS AND MITES AFFECTING SHOOTS (continued)



Some portion of germinant or seedling consumed; needles chlorotic or mottled; growth stunted or distorted

Tissue Not Consumed

Tissue Consumed — See Page 16

Insects covered with cottony wool, waxy wool or silky webbing

Insects not covered with wool, wax or webbing

On *Abies*

On Douglas-fir or spruces

Only on spruces

Numerous hosts

In coastal nurseries

In nurseries throughout province

BALSAM WOOLLY APHID
Small, wool-covered insect causing growth deformities on *Abies* shoots; aphids occur singly over whole seedling; not yet found in nurseries. (page 66)

PRIMITIVE WOOLLY APHID
Small, wool-covered insect causing growth deformities on shoots; aphids occur in masses on seedling shoots; affects spruces in nurseries province-wide. (page 66)
No picture available.

GREEN SPRUCE APHID
Damage confined to coastal localities, particularly on Sitka spruce, also on Douglas-fir and pines. Adults green (1 mm long), feeding causes defoliation, sooty moulds on affected foliage. (page 66)

COOLEY SPRUCE GALL APHID
Insects covered with cottony wool; usually on 1+0 or 2+0 Douglas-fir, sometimes spruces; mainly bareroot, coastal nurseries; spring through mid-summer. (page 66)

SPRUCE SPIDER MITE
Insects and foliage covered with silky webbing; many hosts, 1+0 or 2+0 stock, late summer or fall; needles chlorotic, mottled or bleached. (page 71)

Damage evident, pest inconspicuous or often not seen

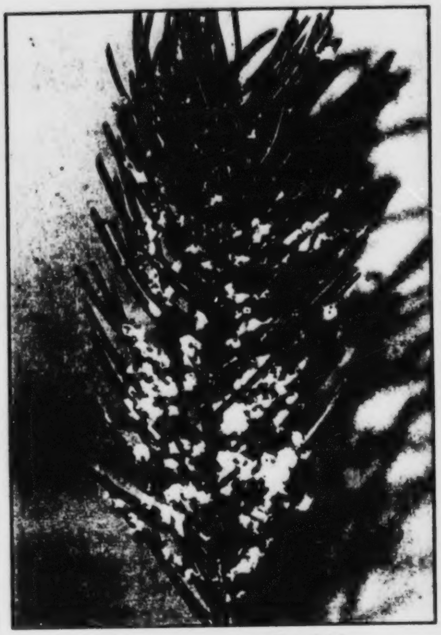
Large, conspicuous aphid usually present

GIANT CONIFER APHID
Large dark aphids feeding on twigs and branches of 1+0 or 2+0 bareroot and container stock, summer through fall; several hosts; honeydew produced. (page 66)

TRISETACUS MITE
Affects lodgepole (especially interior provenances) and shore pines in coastal localities; mites live in needle sheath causing browning and necrosis at needle base, foliage chlorotic, stunted or twisted. (page 71)

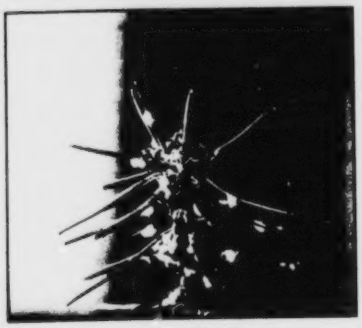
LYGUS BUG
Adults (yellow/reddish-brown, 7x3.5 mm) and immatures feed throughout growing season on 1+0 and 2+0 container and bareroot seedlings causing multiple leaders, and terminal distortion, needles thick, short, twisted; pine preferred but all species can be attacked; province-wide. (page 69)

Giant conifer aphid

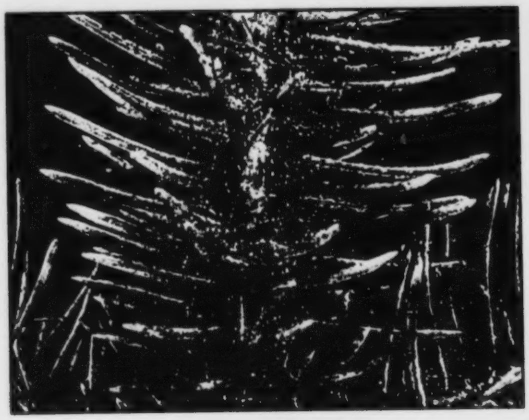


Cooley spruce gall aphid

Lygus bug



Balsam woolly aphid



Spruce spider mite

Trisetacus mite

Green spruce aphid

Diseases Affecting Seeds, Roots, or Root Collar Area

Damping-off

Damping-off is a general term applied to the rotting of seeds, germinants, and succulent seedlings. There are two stages: pre-emergence damping-off kills seeds and germinants before they emerge, post-emergence damping-off affects young seedlings after emergence. Both diseases occur in bareroot and container nurseries throughout the province. In containers, damping-off pathogens are often introduced as seed-borne inoculum, or via contaminated water or growing media. In bareroot nurseries, losses are mainly caused by soil-borne fungi, especially *Fusarium* and *Pythium*.

Losses in local bareroot nurseries are usually less severe than elsewhere in North America, probably because of the absence or scarcity of well-known damping-off fungi such as *Rhizoctonia*, *Phytophthora*, and *Cylindrocladium*. The presence of antagonistic micro- organisms in bareroot nurseries in British Columbia may also account for the relatively low damping-off losses. However, some losses do occur each year in all nurseries throughout the province and they are occasionally severe in bareroot fields with heavier soils and long histories of nursery or agricultural use. Part of the germination failures usually attributed to poor seed viability in bareroot and container nurseries may be caused by seed-borne fungi (see next chapter).

Hosts and damage

Seeds and seedlings of all locally grown species suffer from both pre- and post-emergence damping-off. Failure of germinants to emerge is the only aboveground evidence of pre-emergence damping-off; indeed, damage may go unnoticed unless it is severe or confined to patches. Both affected seeds and germinants that have not yet emerged are rotted. Cool, wet, or compacted soil or growing medium all reduce germination and emergence rates and increase losses from this disease. High humidity, dense sowing in bareroot seedbeds, and multiple sowing in container cavities also favor the disease.

The main symptoms of post-emergence damping-off (Figure 10) are rotting of the stem slightly above and below groundline, and subsequent toppling of the shoot. Dead shoots sometimes dry out and blow away. If the seedling has been attacked during emergence, only the hypocotyl crook will be visible and the germinant will not develop further. Seedlings are susceptible to this disease until their stems become woody, usually 4-6 weeks following emergence. Ordinarily, only random seedlings in bareroot drill rows (Figure 11) are affected but, under ideal conditions, the pathogen may spread and kill small patches of seedlings. Post-emergence damping-off in containers, although uncommon, often occurs in patches resulting from water-spread inoculum.

Life history (Figure 12)

Most damping-off fungi are unspecialized pathogens with similar life histories. Frequently, the same pathogen can be isolated from several seedling species affected by either pre- or post-emergence damping-off. The pathogen overwinters and survives other adverse periods as thick-walled spores, usually in small root pieces and other organic matter. In spring, in proximity to seeds or growing roots, they germinate and infect. Several types of sexual and asexual spores may be produced, and serve in disease spread while the seedlings are susceptible. Most damping-off fungi have only limited ability to grow through soil. As mentioned earlier, some pre-emergence damping-off fungi may be seed-borne.

Management

Management is better based on prevention rather than on cure. The first and best prevention for bareroot nurseries is to select a site with a light soil because disease is invariably less prevalent and control, if required, is easier. Rapid germination, which reduces pre-emergence damping-off losses because the germinants escape the pathogen, may be achieved by: (i) spring sowing stratified seeds, (ii) covering seeds with non-compacting sand or grit, and (iii) sowing when soil or growing medium temperature and moisture are optimum for germination.

Some practices place the pathogen at a nutritional or survival disadvantage .e.g., maintaining or adjusting pH (by adding lime or sulphur) to between 4.5 and 6.0, thus hindering growth of some pathogens but not of seedlings; and bare fallowing between bareroot crops, which promotes depletion of pathogen food bases. Addition of nitrogenous fertilizers to young germinants promotes succulent growth and increases susceptibility, but adequate soil

Damping-off

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	1 + 0	Late spring and early summer	Yes	Yes	Yes	Yes

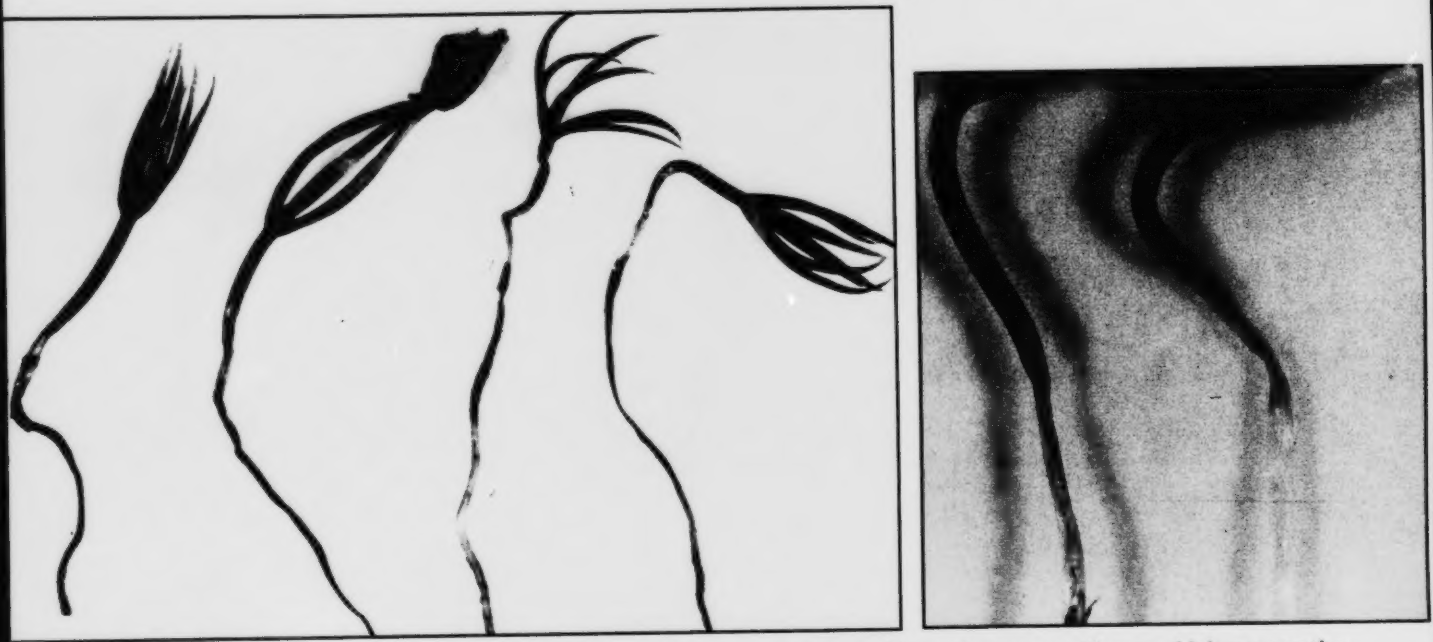


Figure 10. Symptoms of post-emergence damping-off. Note the rotted stem at groundline and compare with sunscald damage on the two germinants at right.

or growing medium fertility levels – especially of phosphorus, potassium, and calcium – promotes development of woody tissues resistant to post-emergence damping-off.

Overcrowding of seedlings, high humidity, and poor air-circulation or drainage all favor post-emergence damping-off; thus, regulation of sowing densities and watering alleviates disease development and spread. Increasing sowing densities to compensate for anticipated damping-off losses is not recommended.

In the past, pre-plant pelleting or dusting of seeds with a fungicide was used for pre-emergence damping-off control in bareroot nurseries. This practice is seldom recommended today because when disease incidence is low or moderate, as in most British Columbia nurseries, the fungicide's phytotoxic effects frequently exceed the losses from damping-off. Fungicide treatment of seeds may be ineffective because: (i) the active spectrum of most fungicides is too narrow to be effective against the numerous kinds and strains of damping-off fungi, (ii) resistant fungus populations develop as the pesticide eliminates the more susceptible strains, and (iii) the fungicide is soon leached off the seed. Thus, if conditions favoring damping-off are prolonged, protection against

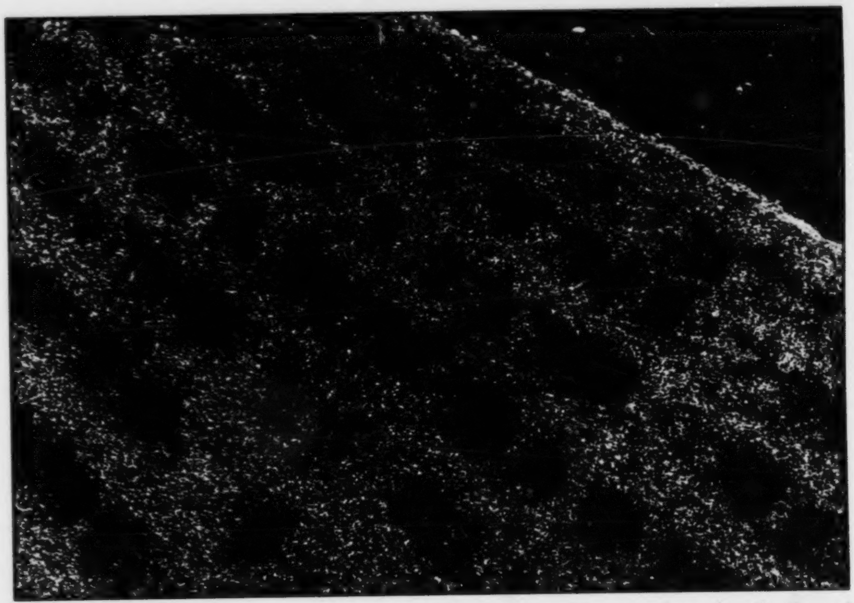


Figure 11. Post-emergence damping-off of yellow pine. Note random distribution of diseased seedlings.

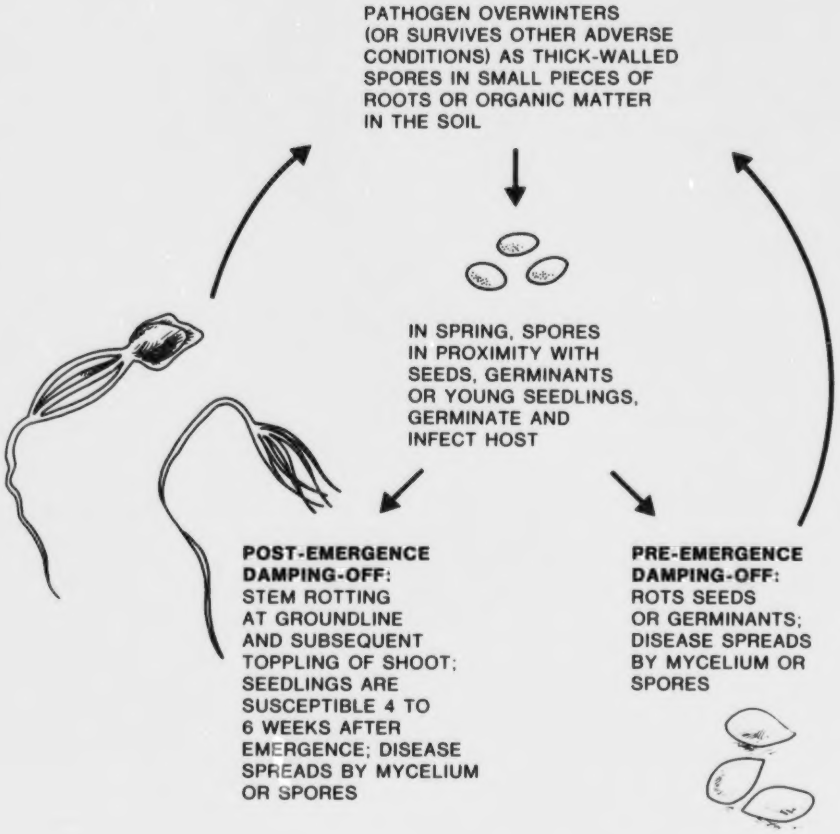

PATHOGEN OVERWINTERS (OR SURVIVES OTHER ADVERSE CONDITIONS) AS THICK-WALLED SPORES IN SMALL PIECES OF ROOTS OR ORGANIC MATTER IN THE SOIL
IN SPRING, SPORES IN PROXIMITY WITH SEEDS, GERMINANTS OR YOUNG SEEDLINGS, GERMINATE AND INFECT HOST
POST-EMERGENCE DAMPING-OFF: STEM ROTTING AT GROUNDLINE AND SUBSEQUENT TOPPLING OF SHOOT; SEEDLINGS ARE SUSCEPTIBLE 4 TO 6 WEEKS AFTER EMERGENCE; DISEASE SPREADS BY MYCELIUM OR SPORES
PRE-EMERGENCE DAMPING-OFF: ROTS SEEDS OR GERMINANTS; DISEASE SPREADS BY MYCELIUM OR SPORES

Figure 12. Life history of pre-and post-emergence damping-off.

attack is too brief.

The harmful effects of seed-applied fungicides are often more prominent in container than in bareroot nurseries because the biological and chemical "buffering capacity" of container growing media is very low. Their use on container-sown seeds is usually not recommended because they can sometimes be phytotoxic. Such damage can be confused with post-emergence damping-off.

Fungicide drenches are sometimes applied to control pre- and post-emergence damping-off. For reasons mentioned above, they are seldom effective and are expensive to apply. Soil fumigation is a standard practice in many North American bareroot nurseries, but because of its expense and harmful effects on mycorrhizal fungi, it probably can be justified only in bareroot nurseries with multiple pest problems (e.g., damping-off, insects, and weeds). It is more practical to follow a fallow rotation, choose a better nursery site, or grow seedlings in containers.

Selected References

Bloomberg, W.J. 1971. Diseases of Douglas-fir seedlings caused by *Fusarium oxysporum*. Phytopathology 61: 467-470.

Lock, W., J.R. Sutherland, and L.J. Sluggett. 1975. Fungicide treatment of seeds for damping-off control in British Columbia forest nurseries. Tree Planters' Notes 26(3): 16-18, 28.

Salisbury, P.J. 1954. A review of damping-off of Douglas-fir seedlings in British Columbia. For. Chron. 30: 407-410.

Seed fungus

This seed-borne pathogen was first reported in Ontario bareroot nurseries in 1964 on fall-sown pine seeds which had failed to germinate. It was next identified as an important pathogen in Britain on Sitka spruce seeds imported from western North America. Based on its asexual spore stage, the fungus was named *Geniculodendron pyriforme*. Subsequently, however, *Caloscypha fulgens* (Figure 13) was found to be the fungus' sexual state, and taxonomically this name has priority.

Hosts and damage

In British Columbia, the pathogen has been found in about 25% of all stored spruce seed (Sitka, Engelmann, white, and Engelmann x white hybrid) and some Douglas-fir and grand fir seedlots. The fungus is pathogenic to seeds of these (Figure 14) and several other conifers. Although exact losses have not been determined for local nurseries, the fungus causes significant pre-emergence losses in Ontario and British bareroot nurseries. In British Columbia, experiments have shown that losses of container-sown Sitka spruce seeds increase with prolonged, cool, post-sowing temperatures. However, losses in container nurseries should be less severe because intercavity spread by the fungus would be difficult.

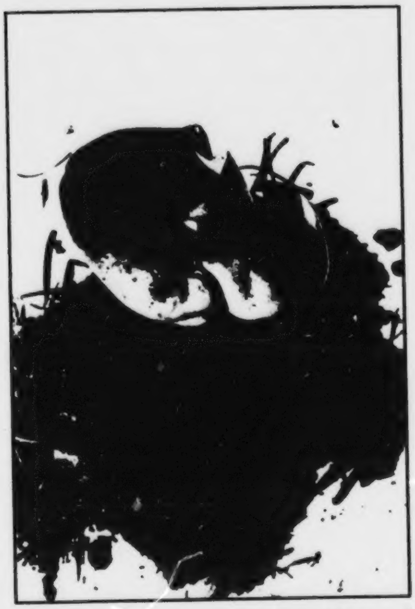


Figure 13. Perfect (sexual) state of the seed fungus.

Since diseased seeds do not germinate, the disease has no above-ground symptoms. Thus, a cursory diagnosis might not differentiate this problem from poor seed viability or pre-emergence damping-off. The contents of *C. fulgens*-killed seeds, however, are firm and mummified, whereas seeds destroyed by damping-off have rotten contents.

Life history (Figure 15)

Caloscypha fulgens inhabits forest duff, and consequently, cones picked from the ground – especially from squirrel caches – may contain diseased seeds. Incidence of diseased seeds depends upon several factors, especially the length of time cones are on the ground. Because the pathogen is known to spread during stratification (Figure 16) and in seedbeds, or within individual container cavities, low levels of diseased seeds are also important. Seeds of some species likely escape fungus infection because their cones are collected directly from trees or, as in the case of lodgepole pine, the cones are tightly closed. Neither sexual nor asexual spores play any apparent role in inoculation; rather, they probably serve only in fungus dissemination.

Within infested seedlots, 1-35% of the seeds are infected and it is from these seeds that the fungus spreads during stratification. The problem can intensify further if moist, stratified seeds are cold-stored at the nursery prior to sowing. Additional spreading and killing can occur following seed sowing, particularly during prolonged periods of cool, wet weather.

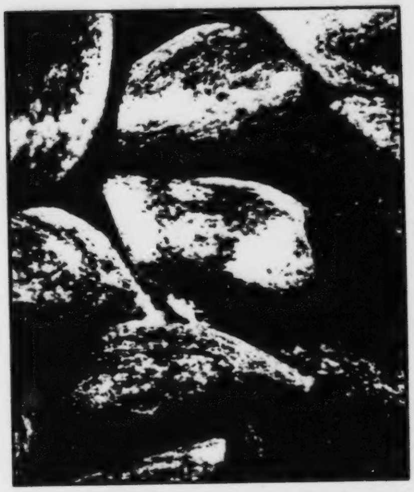


Figure 14. Whitish, crust-like mycelium of the seed fungus on Engelmann spruce seeds.

Management

Sowing non-infested seeds provides the most effective means of prevention, but this is not always practical. Within infested seedlots, fungus spread is confined to the post-storage period because very low storage temperature and moisture prevent *C. fulgens* growth. Optimum temperature for growth of the pathogen is 20°C; thus, stratifying seeds at the lowest temperature possible (e.g., 1 or 2°C) helps to hinder pathogen growth. Shortening the stratification period also reduces, but does not eliminate, disease risk because even at 1 or 2°C, appreciable fungus growth occurs after 3-4 weeks. Compared to stratification in sand or other media, fungus spread is less when seeds are naked-stratified. Since the fungus inhabits forest duff, such material should not be added to seedbeds (e.g., to provide mycorrhizal inoculum) without first ensuring that it is free of the pathogen.

In Britain, adding a fungicide to the water used to soak seeds prior to chilling has reduced pathogen spread during stratification. In Ontario and Britain, applying a fungicide to seeds before sowing has also been beneficial. Because the pathogen attacks only dormant seeds, infested seed-

Seed fungus

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Grand fir, all spruces, Douglas-fir	Seed	Spring to early summer	Yes	Yes	Yes	Yes

lots should not be sowed until soil or growing medium temperatures are high enough for rapid germination. This applies to bareroot and container operations, especially when seedlots do not receive a pre-sowing fungicide dusting, or when container cavities are multiple sown to compensate for low seed viability.

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Salt, G.A. 1974. Etiology and morphology of *Geniculodendron pyriforme* gen. et sp. nov., a pathogen of conifer seeds. Trans. Brit. Mycol. Soc. 63: 339-351.

Sutherland, J.R. 1979. The pathogenic fungus *Caloscypha fulgens* in stored conifer seeds in British Columbia and relation of its incidence to ground and squirrel-cache collected cones. Can. J. For. Res. 9: 129-132.

Thomson A.J., J.R. Sutherland, T.A.D. Woods, and S.M. Moncrieff. 1983. Evaluation of seed disease effects in container-sown Sitka spruce. For. Sci. 29: 59-65.

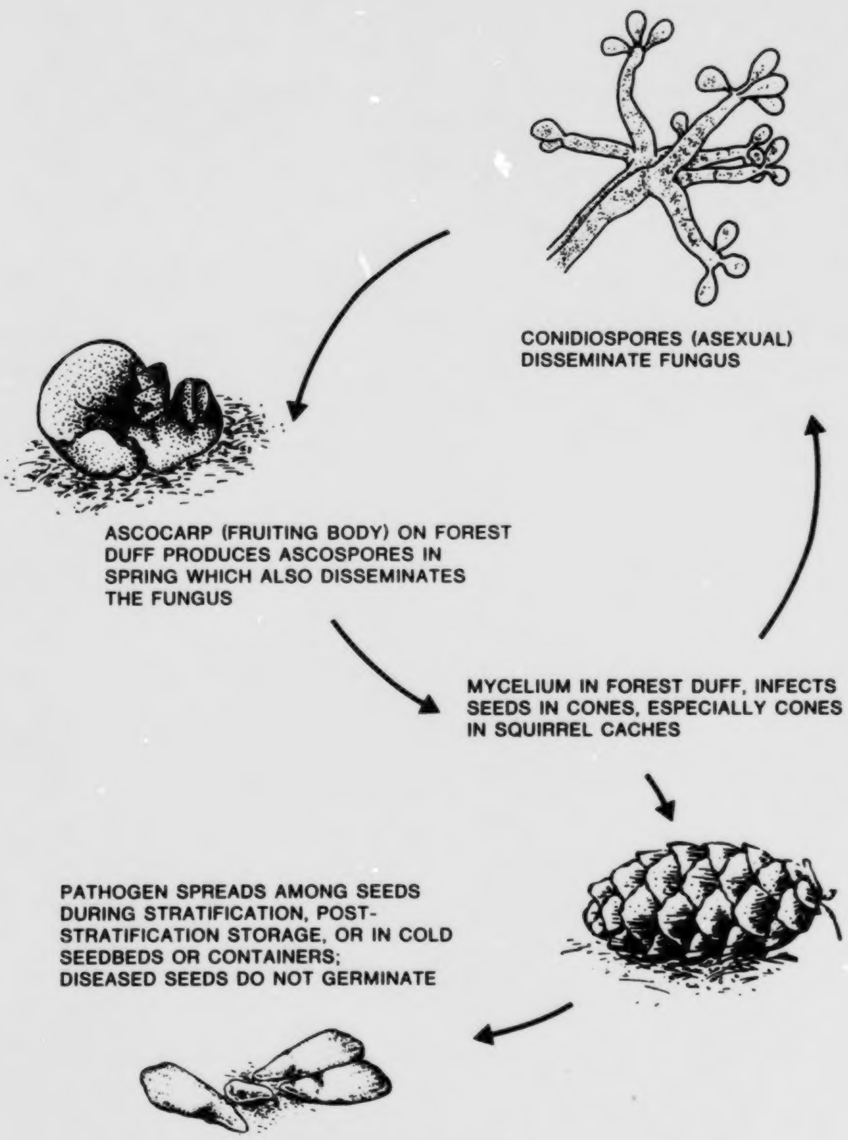
CONIDIOSPORES (ASEXUAL) DISSEMINATE FUNGUS
ASCOCARP (FRUITING BODY) ON FOREST DUFF PRODUCES ASCOSPORES IN SPRING WHICH ALSO DISSEMINATES THE FUNGUS
MYCELIUM IN FOREST DUFF, INFECTS SEEDS IN CONES, ESPECIALLY CONES IN SQUIRREL CACHES
PATHOGEN SPREADS AMONG SEEDS DURING STRATIFICATION, POST-STRATIFICATION STORAGE, OR IN COLD SEEDBEDS OR CONTAINERS; DISEASED SEEDS DO NOT GERMINATE

Figure 15. Life history of the seed fungus.

Figure 16. Mycelium of the seed fungus growing on stratified Sitka spruce seeds.

Fusarium root rot

This disease, caused by several *Fusarium* species, has become a recent concern in both container and bareroot nurseries. In containers, inoculum is often borne on seeds, in water, in contaminated growing media, or on used styroblocks. Coastal, bareroot nurseries on heavier soils generally have the highest incidence of the disease.

Hosts and damage

Douglas-fir, lodgepole pine, and Engelmann and white spruce are the principal hosts, but white pine, western hemlock, and larch are also affected. Shoot symptoms appear on random seedlings in drill rows (Figure 17) as early as mid-July (i.e., when post-emergence damping-off is declining), and may continue to appear until late fall. In both container and bareroot nurseries, high temperatures and drought predispose seedlings to the disease and contribute to rapid symptom development. The disease is frequently more prevalent in certain seedbeds or seedlots.

Initial symptoms are most evident on the shoot and include chlorosis of terminal needles, followed by all needles becoming flaccid, often turning purplish, and then becoming brown and dried out (Figure 18). The shoot tip frequently bends into a shepherd's crook. Since the stem is woody, it remains upright, distinguishing this disease from damping-off. Although shoot symptoms are the first to be noticed, they actually indicate a root problem. Diseased root systems have few laterals and the remaining roots are often dark, swollen, and lacking an actively growing white root tip. The bark and cortex of affected roots can be easily stripped away to expose the darkened cambium. The disease is usually fatal, but sometimes it destroys only the primary root, resulting in a deformed root system and stunted shoot. Such seedlings are culls.

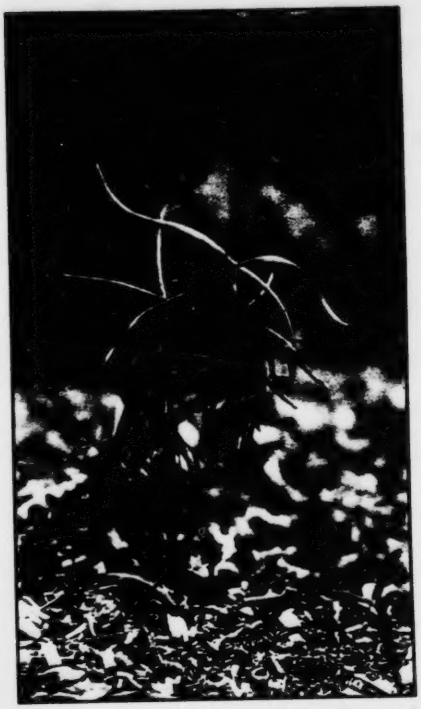

Figure 18. Douglas-fir showing advanced shoot symptoms of *Fusarium* root rot.

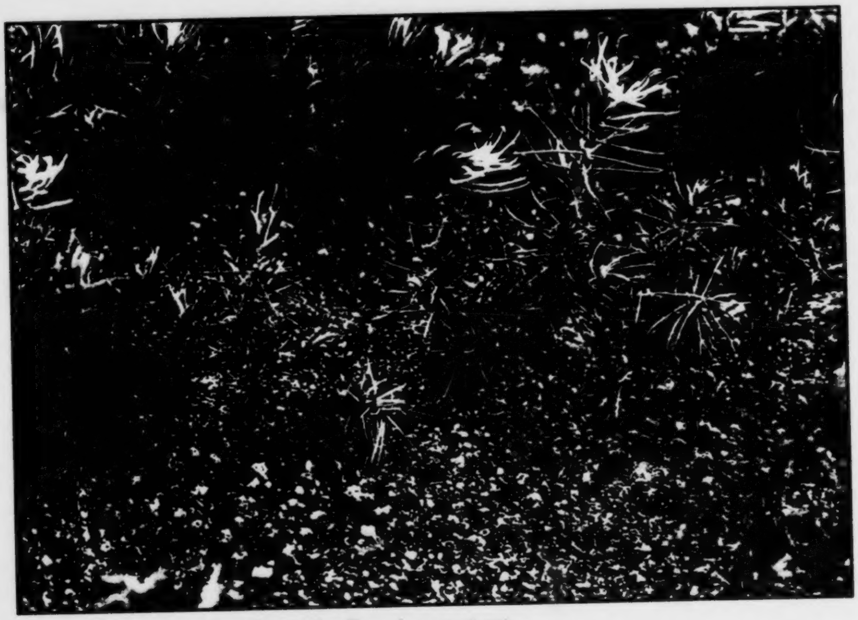

Figure 17. Douglas-fir affected by *Fusarium* root rot.

***Fusarium* root rot**

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Douglas-fir lodgepole pine, Engelmann and white spruces, sometimes other species	1 + 0, rare on 2 + 0	Mid-summer to late fall	Yes	Yes	Yes	Yes

Life history (Figure 19)

This disease is caused by a form of the same fungus that frequently causes damping-off; thus, many aspects of the life history are similar. For example, the pathogen overwinters as chlamydospores in small pieces of roots or organic matter, and when seedling roots grow near these spores, germination occurs and the pathogen enters the roots. However, development is delayed until later in the growing season, when larger and more crowded seedlings are stressed for moisture and nutrients. The fungus then grows rapidly throughout the root system and destroys it. Warm

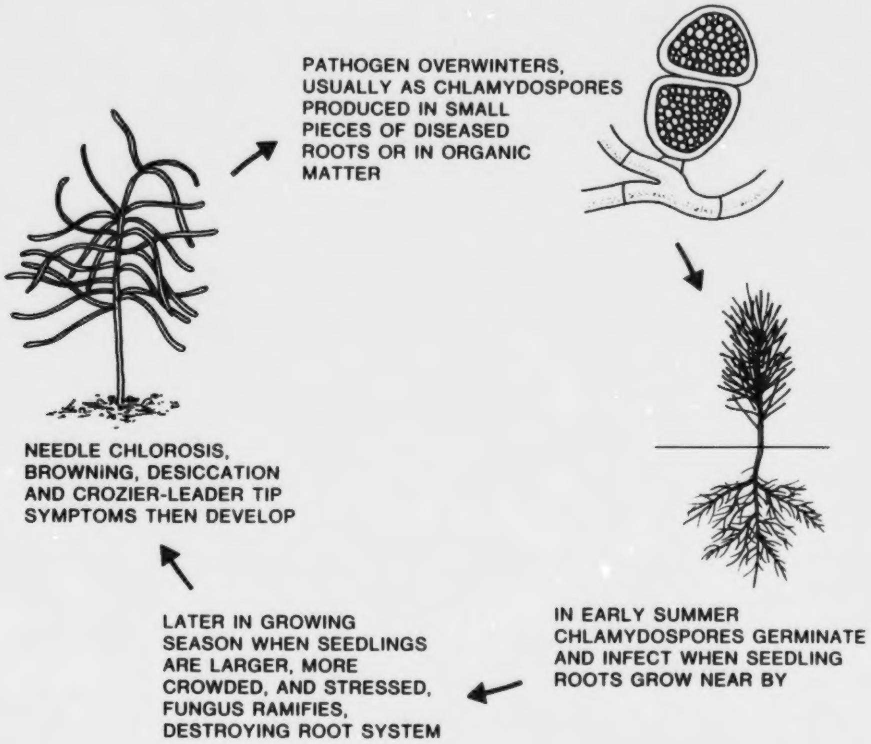
PATHOGEN OVERWINTERS, USUALLY AS CHLAMYDOSPORES PRODUCED IN SMALL PIECES OF DISEASED ROOTS OR IN ORGANIC MATTER
IN EARLY SUMMER CHLAMYDOSPORES GERMINATE AND INFECT WHEN SEEDLING ROOTS GROW NEAR BY
LATER IN GROWING SEASON WHEN SEEDLINGS ARE LARGER, MORE CROWDED, AND STRESSED, FUNGUS RAMIFIES, DESTROYING ROOT SYSTEM
NEEDLE CHLOROSIS, BROWNING, DESICCATION AND CROZIER-LEADER TIP SYMPTOMS THEN DEVELOP

Figure 19. Life history of *Fusarium* root rot.

soil favors disease development. The sources of inoculum on container-grown seedlings is unclear; however, *Fusarium* can be seed-borne or infection may result from wind-borne spores.

Management

Disease losses can be reduced in container nurseries that have a well- drained and aerated growing medium and that use irrigation regimes for preventing stress. Used containers should be thoroughly cleaned (according to current recommendations) because *Fusarium* can occur on them. In bareroot nurseries, heavy soils favor the pathogen, supposedly because of the slower decomposition rate of the pathogen's food bases (e.g., root pieces). The disease can be effectively prevented by locating bareroot nurseries on lighter soils.

Bare fallowing between seedling crops and removal of plant debris following seedling lifting reduces losses by increasing the rate at which the pathogen exhausts its available food. Sawdust mulching and irrigation, which reduce soil temperatures, may also be helpful. Culling infected seedlings helps reduce disease spread in container and bareroot nurseries.

Practices that reduce seedling moisture and nutrient stresses are important in *Fusarium* management. To date, fungicides have proven to be ineffective, probably because the pathogen enters very young plants and symptoms do not develop until much later. By then, the disease has advanced beyond control, especially if disease detection relies on shoot symptoms. Soil fumigation is too expensive to be used solely for controlling the disease.

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Pythium root rot

Pythium root rot can affect bareroot and container seedlings in British Columbia. This is particularly true where: (i) soil or growing medium drainage is poor, (ii) temperature is unfavorable for root development, and (iii) the same seedling species is grown in a field over several years.

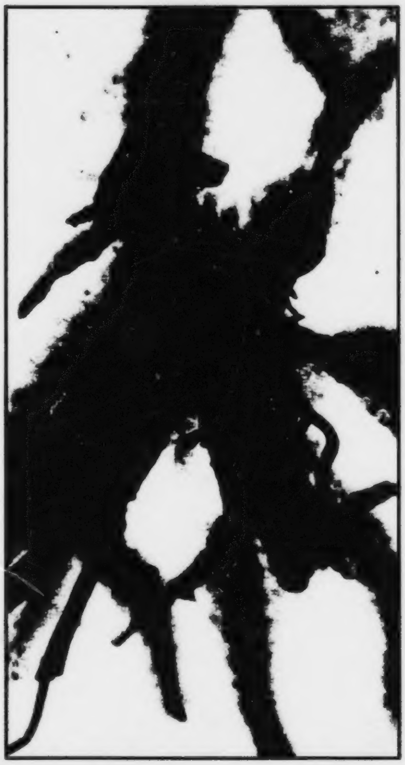

Figure 20. *Pythium* root rot on bareroot Douglas-fir.

Hosts and damage

Pythium species are ubiquitous in soil and aquatic environments and they have a wide host range. *Pythium* root rot (Figure 20) is usually restricted to juvenile or succulent tissues or, on older plants, to root tips or lateral roots. Mature, lignified tissues are seldom affected. Infection results in poorly developed root systems, shoot stunting, and chlorosis. Severely diseased seedlings (Figure 21) rarely reach minimal grading standards (by size). Depending upon numerous factors, including soil or growing medium, moisture level, infection often occurs at or slightly below the root collar.

In containers (Figure 22), the bottom of the growing cavity often remains wet for prolonged periods, providing ideal conditions for infection. The pathogen enters through root tips, proliferating in young cells and causing rapid collapse and rootlet death. Spread into older roots is limited to the cortex.

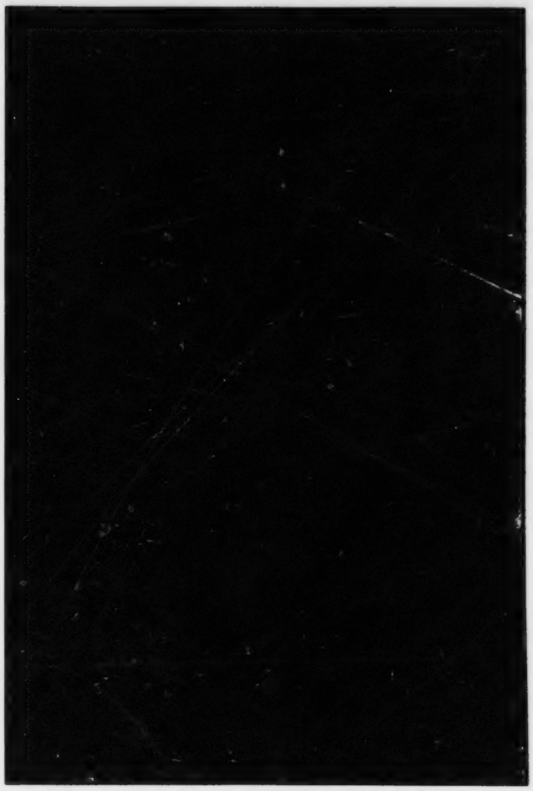

Figure 21. *Pythium* root rot on Douglas-fir.

Life history (Figure 23)

Pythium species can survive for long periods as thick-walled resting spores (oospores) or as saprophytes on dead organic matter. They are weak competitors, and thus survival as mycelium is uncommon. Survival and infection are primarily through zoospores and sporangia for short and intermediate periods, and oospores for longer periods. Oospores are resistant to extreme temperatures and other adverse conditions, and remain viable in soil for several years. Germination is stimulated by increased moisture or the presence of the host root. From 10–18°C, infection is through zoospores produced by both oospores (sexual) and sporangia (asexual). Zoospores travel short distances through the soil water, attracted to the host's root exudates. Infection at higher temperatures usually results from direct germination of oospores and sporangia.

***Pythium* root rot**

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All spruces, Douglas-fir, sometimes other species	1 + 0 2 + 0	Usually late summer through following spring	Yes	Yes	Yes	Yes

Management

Pythium root rot is seldom a problem when either the bareroot soil or container growing medium are well drained and slightly acid. Selecting a bareroot site with such soil helps alleviate *Pythium*-caused problems. Proper water management is a key component of control. Sometimes soil fumigation or fungicide drenches in bareroot nurseries, or just the latter in containers, is justified. The problem may carry over from one crop to the next, intensifying with time (e.g., on root pieces in bareroot nurseries and on used styroblocks in container nurseries). *Pythium*-free peat should be used in both bareroot and container nurseries. When diseased stock is

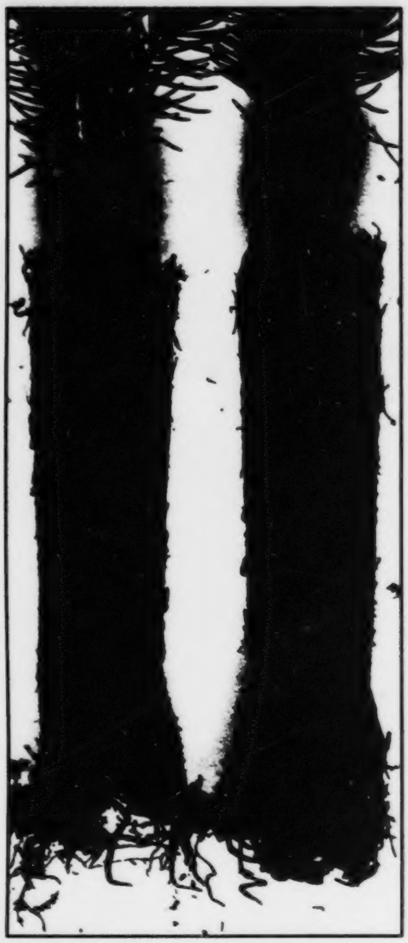

Figure 22. *Pythium* root rot on container-grown spruce. Note that damage is most severe on roots lower in the container.

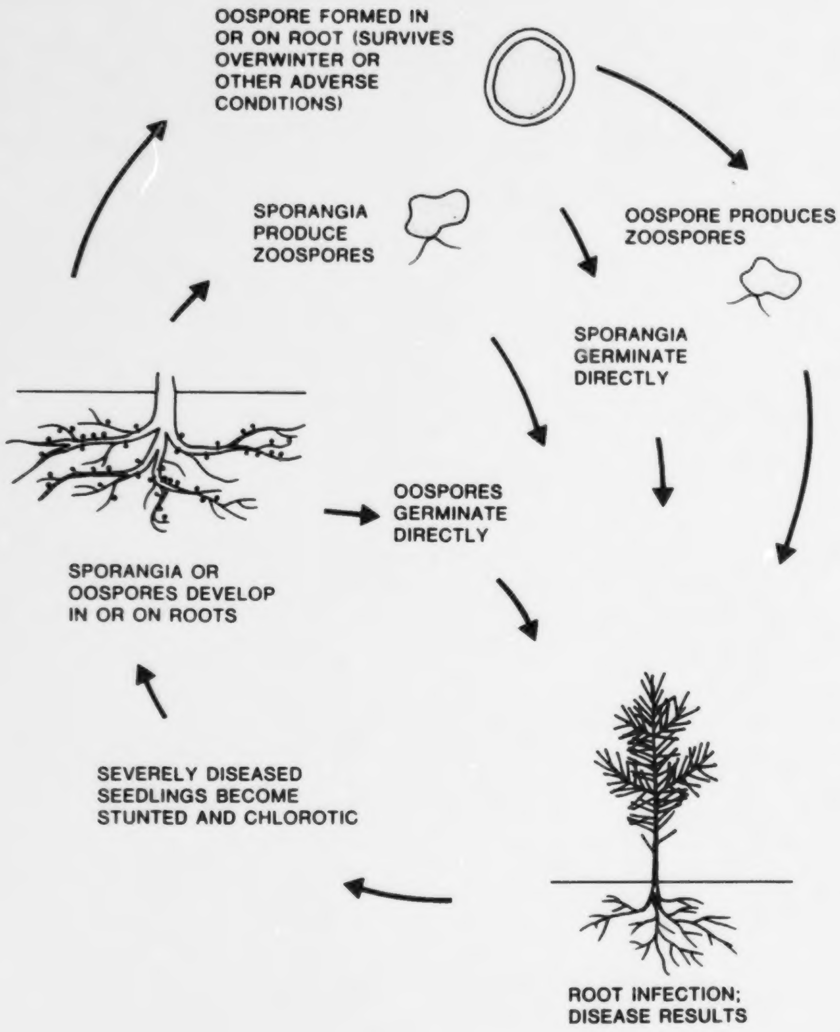
OOSPORE FORMED IN OR ON ROOT (SURVIVES OVERWINTER OR OTHER ADVERSE CONDITIONS)
OOSPORE PRODUCES ZOOSPORES
SPORANGIA PRODUCE ZOOSPORES
SPORANGIA GERMINATE DIRECTLY
OOSPORES GERMINATE DIRECTLY
SPORANGIA OR OOSPORES DEVELOP IN OR ON ROOTS
SEVERELY DISEASED SEEDLINGS BECOME STUNTED AND CHLOROTIC
ROOT INFECTION; DISEASE RESULTS

Figure 23. Life history of *Pythium* root rot.

lifted, care should be taken not to leave diseased roots, as they serve as refugia for the pathogen. Styroblocks should be thoroughly sanitized between crops. Irrigation water, especially from ponds or reservoirs that receive run-off from *Pythium*-infected areas, can be a source of inoculum. Chlorination of contaminated water may be justified.

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Gill, D.L. 1970. Pathogenic *Pythium* from irrigation ponds. Plant Disease Rep. 54: 1077-1079.

Hendrix, F.F. Jr. and W.A. Campbell. 1973. Pythiums as plant pathogens. Ann.Rev. Phytopathol. 11: 77-98.

James, R.L. 1982. *Pythium* root disease of Douglas-fir and grand fir seedlings at the Coeur d'Alene Nursery, Idaho. U.S. Dep. Agric. For. Serv., North. Reg. Rep. 82-10.

Cylindrocarpon root rot

For the past few years a species of *Cylindrocarpon*, probably *C. destructans*, has been identified on roots of bareroot and container-grown seedlings in British Columbia. It was first observed in this province in 1963 at the Campbell River nursery, where it was associated with the nematode *Xiphinema bakeri* which causes corky root disease. *Cylindrocarpon* is one of the most common fungi found on plant roots, yet the degree of its pathogenicity on conifer seedlings remains unclear. Likely, it is an important factor when seedlings are predisposed by stress (Figure 24).

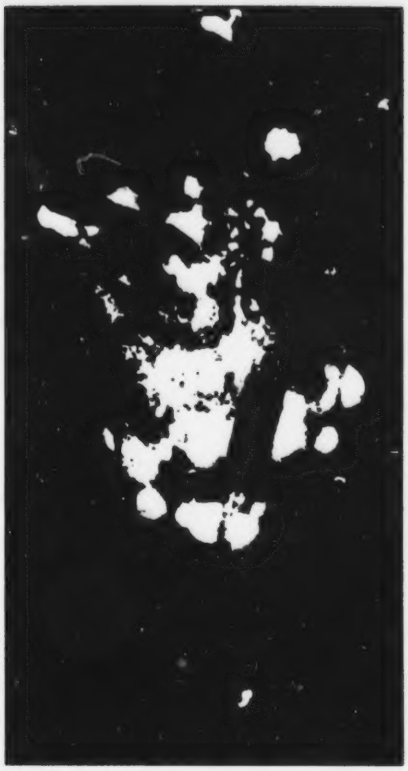

Figure 24. *Cylindrocarpon* sporulating on the stem of a white spruce seedling.

Hosts and damage

In both bareroot and container nurseries, *Cylindrocarpon* occurs on Douglas-fir, Engelmann and white spruce, and occasionally lodgepole pine, white pine, western hemlock, and Sitka spruce. Diseased roots (Figure 25) appear dark brown and stunted, and may be rotted. In the nursery, root infection may cause shoot stunting later in the growing season. *Cylindrocarpon* root rot may reduce root regeneration capacity or, when damage is minimal, go undetected during seedling grading. Both factors could reduce survival of field-planted seedlings.

Life history[1]

Cylindrocarpon occurs in soil as a saprophyte or weak pathogen associated with roots of many herbaceous and woody plants. Mycelial growth plays a major role in the survival of the fungus in soil and its spread to new substrates. Conidiospores and chlamydospores are also produced.

Cylindrocarpon is found in the upper and lower soil horizons, and colonizes roots to a greater extent in the latter because it can grow at low oxygen concentrations. It is considered a pioneer colonizer of young root tips due to its great competitive ability, rapid spore germination and mycelial growth, and physiological features such as its ability to use both inorganic and organic nitrogen. It grows rapidly even at low nutrient concentrations, enabling it to colonize new substrates before other fungi. *Cylindrocarpon* is common in alkaline soils.

Management

In bareroot nurseries, bare fallowing and disking between crops to expose mycelium, conidiospores, and chlamydospores, is a good practice. Maintaining good drainage and sanitation practices in bareroot and container nurseries helps prevent the problem. In the latter, styroblocks should be sanitized between crops. Preventing seedling stress may alleviate the disease. The effectiveness of fungicide drenches against *Cylindrocarpon* is not yet known, particularly for British Columbia's conditions.

Selected References

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Kowalski, S. 1982. Role of mycorrhiza and soil fungi in natural regenerationof fir (*Abies alba* Mill.) in Polish Carpathians and Sudetes. Eur. J. For. Path. 12: 107-112.

Kubikova, J. 1965. Mycoflora synusias on the roots of woody-plants. Rozpr. Cesk. akad. ved rada mat. prir. ved 75-(8): 1-53.

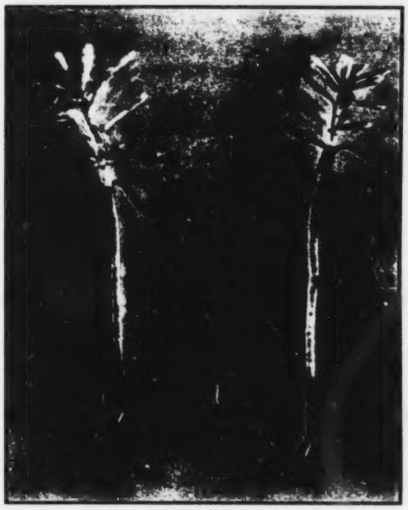

Figure 25. *Cylindrocarpon* damage on western hemlock. Note the dark, stunted roots.

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[1] Because little is known about the life history of *C. destructans*, a diagram is not included here.

Cylindrocarpon root rot

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Douglas-fir, Engelmann and white spruces, sometime other species	1 + 0 2 + 0	All year	Yes	Yes	Yes	Yes

Corky root disease

This disease is caused by the nematode *Xiphinema bakeri*. Most plant-parasitic nematodes are small (0.5-2 mm long) vermiform animals belonging to the phylum Nematoda. Those that damage conifer nursery seedlings are soil inhabitants and feed on non-woody roots and mycorrhizae. Corky root is the only nematode-caused disease that has been important locally. Both the pathogen and the disease are confined to coastal, bareroot nurseries. Corky root normally occurs in nurseries established on recently cleared forest lands. *Xiphinema bakeri* is indigenous to most coastal forests and when these forests are converted to nursery production, the pathogen numbers increase. The nematode populations rarely reach damaging levels on the first crop; however, subsequent crops are severely damaged, especially if cropping is continuous.

Hosts and damage

Locally, the disease affects seedlings of the spruces (Sitka, white, Engelmann), western hemlock, and Douglas-fir, the latter being the most sensitive. Symptoms (Figures 26-28) first become noticeable on Douglas-fir about midway through the first growing season, when the secondary needles of random seedlings become somewhat chlorotic and the shoot slightly stunted (Figure 26). Diseased taproots have few if any laterals, are dark, swollen and often club-tipped, but they are not rotten. Patches of affected seedlings become evident as the symptoms develop and eventually these patches coalesce (Figure 27) to form patches 5-65 m in diameter.

Seedlings affected in their first growing season fail to recover and are culled when lifted. Two-year-old stock (Figure 28) and transplants may also become diseased if *X. bakeri* populations are large. When diseased, small-rooted seedlings such as spruce often frost heave. The fungus *Cylindrocarpon destructans* frequently invades diseased roots, but the nematode is the primary pathogen. Corky root disease prevails in soils that are sandier, less fertile, and lower in nutrient-holding capacity than disease-free soils. The sandier soils are physically better suited for *X. bakeri* movement. Thus, the two prerequisites for optimum disease development are large numbers of the pathogen and low soil fertility.

Life history (Figure 29)

The life cycle consists of eggs, four juvenile stages, and adults. Only the latter are sexually mature; males are rare. The last three pre-adult stages and adults feed on roots. Eggs

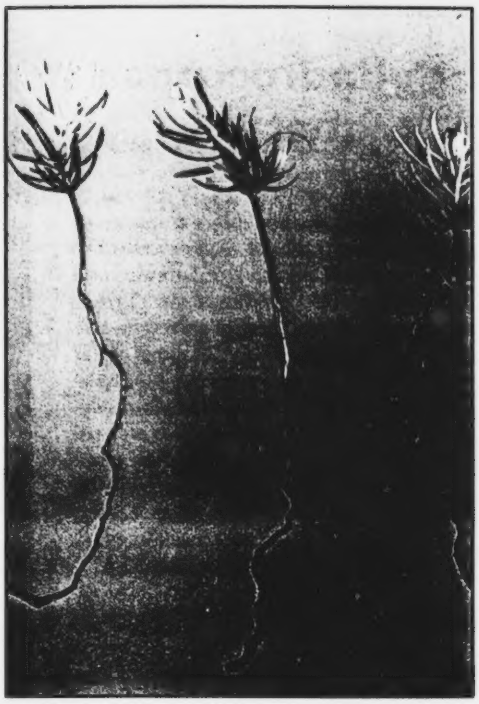

Figure 26. Corky root symptoms on 1+0 Douglas-fir.

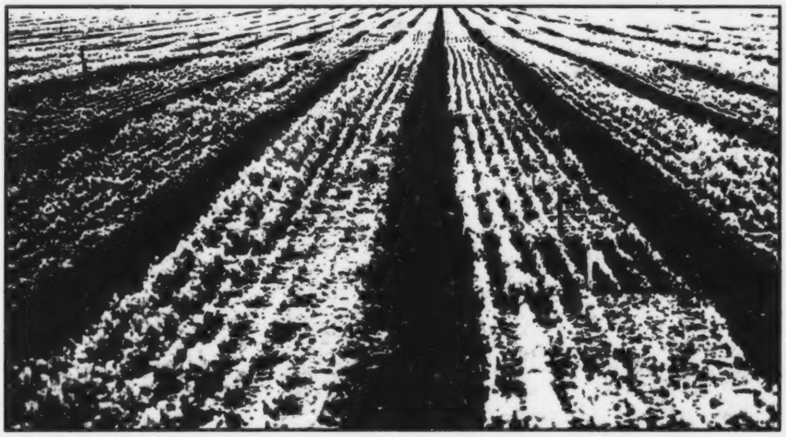

Figure 27. A field of 2+0 Douglas-fir showing corky root symptoms.

Corky root

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All spruces, western hemlock, and especially Douglas-fir	1 + 0 2 + 0	Mid-season on 1 + 0 stock, continues on 2 + 0 stock	Yes	No	No	No

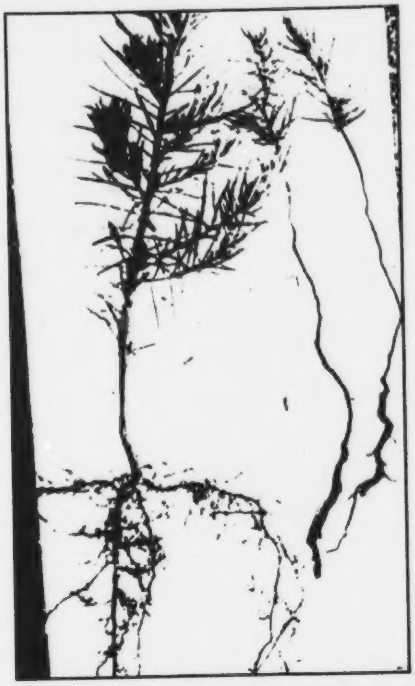

Figure 28. Corky root (two right-hand seedlings) on 2+0 Douglas-fir.

are laid in the summer, total populations peak in early fall, and the nematodes overwinter primarily as eggs and juveniles. Almost all of the nematodes are present in the upper 10 cm of soil around the roots.

Management

Nematode numbers are reduced to non-damaging levels by starvation, heat, and desiccation. Therefore, losses from corky root can be eliminated by bare fallowing, surveying fallow fields in June or July to detect X. *bakeri* populations, and disking or rototilling infested soils during the hot, dry part of August and September. To prevent introduction of the pathogen into disease-free nurseries, fill and other potentially infested soil amendments should be checked for X. *bakeri*. Seedlings, especially diseased ones, should not be transferred among nurseries.

Pre-plant nematicides or soil fumigation can be used, but they are expensive and often adversely affect seedling growth. Because local soil temperatures normally limit application to late summer or early fall, the use of nematicides often results in loss of seedling production for a year.

Selected References

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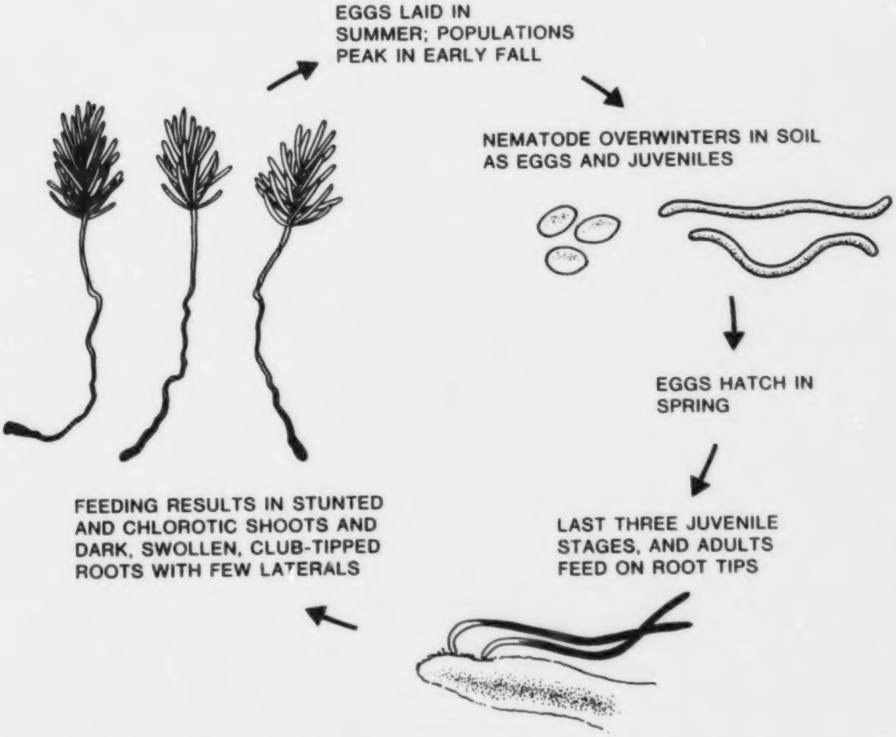
Sutherland, J.R. and L.J. Sluggett. 1974. Time, temperature, and soil moisture effects on *Xiphinema bakeri* nematode survival in fallow soil. Phytopathology 64: 507-513.



EGGS LAID IN SUMMER; POPULATIONS PEAK IN EARLY FALL
NEMATODE OVERWINTERS IN SOIL AS EGGS AND JUVENILES
EGGS HATCH IN SPRING
LAST THREE JUVENILE STAGES, AND ADULTS FEED ON ROOT TIPS
FEEDING RESULTS IN STUNTED AND CHLOROTIC SHOOTS AND DARK, SWOLLEN, CLUB-TIPPED ROOTS WITH FEW LATERALS

Figure 29. Life history of corky root disease.

Diseases Affecting Shoots

Gray mould

This disease occurs in container nurseries throughout the province and provides a classic example of how new pest problems can arise with technological change – the change from bareroot seedling production, where the disease seldom occurs, to growing seedlings in containers. Earlier problems with the disease have decreased with improved cultural conditions.

Hosts and damage

Botrytis cinerea is a ubiquitous fungus with a wide host range; locally, it is very damaging to western hemlock, spruce, and Douglas-fir seedlings. Western redcedar is also attacked, often on the tips of the terminal shoot and lateral branches. Pines seem to be less affected than other species. Some reasons for this are: (i) that they are usually smaller and have a more upright growth habit, both of which limit within-canopy conditions favoring the disease, and (ii) that they are usually grown in nurseries in interior British Columbia where the climate is drier.

Symptoms appear from late summer onward, until stock is shipped for outplanting. Initial symptoms include watery-moulding and killing of lower needles, or sometimes of the leader, branches, and stem. Tan or brown-watery lesions often develop on affected organs. As the disease progresses, the symptoms move upward and the disease can eventually kill the entire shoot. Frequently, webs or masses of gray-brown mycelium (Figure 30) and spores of the pathogen are present on dead tissue-thus the name "gray mould." The disease does not seem to harm roots. Besides affecting seedlings in the nursery, the disease can continue to develop if affected seedlings are cold-stored. This topic is discussed in the chapter on moulding of stored seedlings.

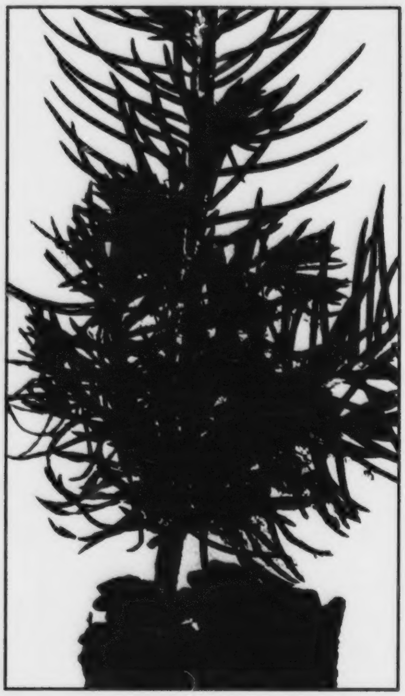


Figure 30. Gray mould on container-grown spruce.

Life history (Figure 31)

The pathogen overwinters as mycelium or sclerotia in old plant debris, but the exact sequence of events is not known for local container nurseries. *Botrytis* conidiospores, which are usually air-borne, are probably produced on dead plant material within the nursery or adjacent fields and forests, and are either drawn or blown into nurseries by ventilation fans or wind. The fungus may also be introduced on seeds, as it can easily be isolated from them. Irrigation water could also contain gray mould spores.

Botrytis cinerea normally becomes parasitic after establishing a food base on dead or dying plant material. Tissues damaged by fertilizer or frost are known avenues for infection. *Botrytis* may also enter seedlings early in the growing season via senescent needles. Disease development and spread are favored by moderate temperatures, high moisture, dense foliage, and crowded seedlings. The disease usually starts on and spreads from senescent, dead, injured, or lower needles. When succulent leaders are attacked, the disease can move downward.

Management

Cultural and fungicidal controls are presently used, alone or combined, against gray mould. The former are aimed mostly at making greenhouse conditions unfavorable for disease development: e.g. (i) lowering humidity, by decreasing or ceasing watering or by watering in the morning so that foliage dries off quickly, (ii) improving ventilation by spacing of containers so that there is a space between each one, (iii) regulating temperature, or (iv) using any

Gray mould

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Douglas-fir, western hemlock, all spruces, other species less severely affected	1 + 0 2 + 0	Late spring onward	Rare	Rare	Yes	Yes

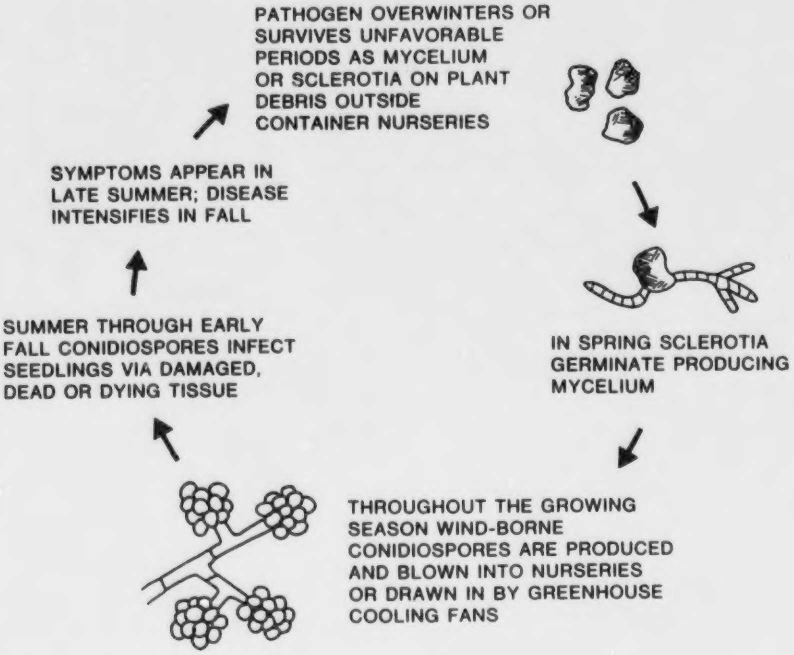

PATHOGEN OVERWINTERS OR SURVIVES UNFAVORABLE PERIODS AS MYCELIUM OR SCLEROTIA ON PLANT DEBRIS OUTSIDE CONTAINER NURSERIES
SYMPTOMS APPEAR IN LATE SUMMER; DISEASE INTENSIFIES IN FALL
SUMMER THROUGH EARLY FALL CONIDIOSPORES INFECT SEEDLINGS VIA DAMAGED, DEAD OR DYING TISSUE
IN SPRING SCLEROTIA GERMINATE PRODUCING MYCELIUM
THROUGHOUT THE GROWING SEASON WIND-BORNE CONIDIOSPORES ARE PRODUCED AND BLOWN INTO NURSERIES OR DRAWN IN BY GREENHOUSE COOLING FANS

Figure 31. Life history of gray mould.

combination of these. Dead, especially *Botrytis*-infected seedlings or other plant material (including weeds), should be removed from within and near container nurseries to reduce gray mould inoculum. Greenhouse ventilation can also be improved by the removal of side and roof coverings. The latter also improves lighting, thus preventing excessive shoot growth which is particularly favorable to gray mould.

Other factors that may contribute to gray mould include seedling moisture stress and, although not yet defined, certain fertilizer regimes. Gray mould that becomes established during the growing season may develop further on stored seedlings. Storing seedlings at -1 to -2°C prevents such damage. However, the stock should be handled carefully after storage to prevent subsequent gray mould damage.

Protectant and eradicant (systemic) fungicides are also used in gray mould management. Factors related to their efficiency include timing of application, thoroughness of coverage, and, in the case of certain systemic fungicides, buildup of *Botrytis* strains with fungicide tolerance. No fungicide, however, will completely control the disease unless the environmental conditions favoring disease development are also changed.

Selected References

Ellis, M.B. and J.M. Waller. 1974. *Sclerotinia fuckeliana* (conidial state: *Botrytis cinerea*). CMI Desc. of pathogenic fungi and bacteria. No. 431. Commonwealth Mycol. Inst., Kew, Surrey, England.

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Rosellinia blight

Rosellinia minor has recently been identified on container-grown seedlings in British Columbia. Previous reports of *R. herpotrichioides* on bareroot Douglas-fir in the province are now attributed to *R. minor*. The moist, mild falls and winters of coastal British Columbia are ideal for *Rosellinia*.

Hosts and damage

Locally, *R. minor* has occurred on 1+0 container-grown Douglas-fir and Engelmann spruce and 2+0 bareroot Douglas-fir. It also affects bareroot Douglas-fir and Sitka spruce in California and Washington, respectively. Damage occurs in the center of densely sown seedbeds, container-nursery benches, or individual containers where prolonged high humidity, free water on stems and needles, and dense foliage favor the disease (Figure 32). The fungus forms dense mats of whitish brown mycelium (Figure 33) on the lowermost stems and needles of seedling shoots, sometimes binding them together.

Superficially, *Rosellinia* can resemble gray mould, *Botrytis cinerea*, which thrives under similar conditions, and sometimes the two occur together. The two fungi differ in that *R. minor* forms sexual fruiting structures (perithecia). *Rosellinia* also has the tendency to grow upward and cover the shoot. Needles beneath the mycelium become chlorotic, die, and are cast, resulting in the seedlings being culled. Few seedlings die. Defoliation can reach 80% on heavily attacked seedlings. After needle death, the mycelium loses its mould-like appearance and becomes flattened against twigs and needles, exposing the small black, perithecia (Figure 34).

Life history[2]

The life history of *Rosellina* is unknown. Infection may result from airborne conidiospores, mycelium from contaminated soil, ascospores, or all three. Generally, perithecia produce ascospores after the decayed host material is subjected to winter temperatures. Conidiospores are produced during summer. Under fa-

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[2] Because little is known about the life history of *R. minor*, a diagram is not included here.

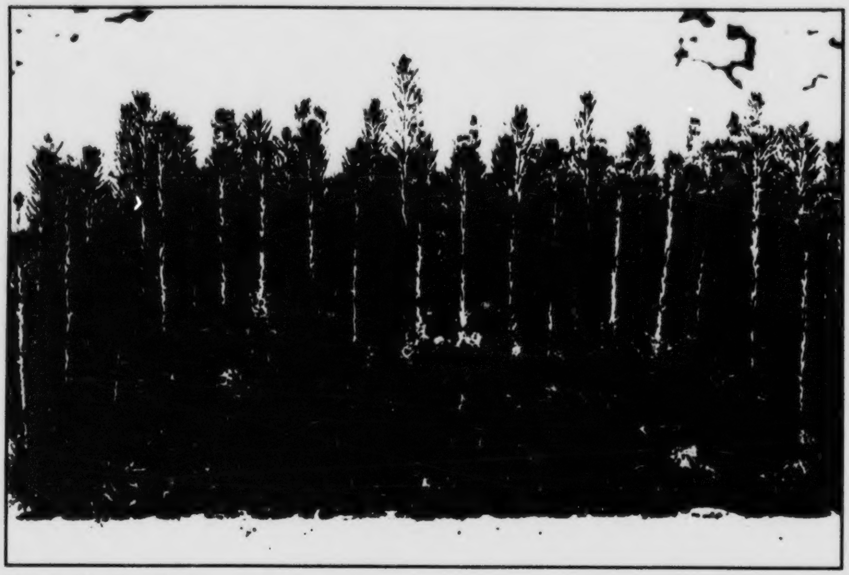

Figure 32. *Rosellinia* on container-grown spruce.

vorable growing conditions this may vary, with ascospores produced and released to start new infection centers the same growing season, while mild winters may result in conidiospore production.

Management

Cultural practices are important in *R. minor* management as the fungus requires long periods of high humidity and free moisture. Humidity can be reduced by spacing containers to improve aeration, decreasing irrigation, and increasing ventilation. Growing media should have good drainage to avoid water accumulation. Sanitation is important, so diseased plant material should be removed from the nursery. In bareroot nurseries, bare fallowing during summer will expose the pathogen to the sun's heat and desiccation.

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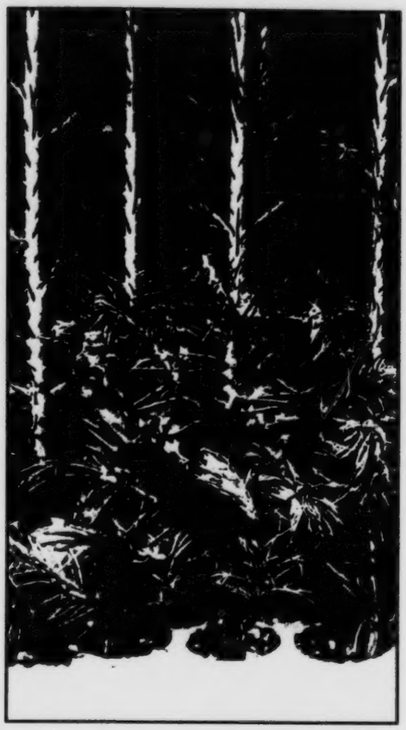

Figure 33. Container-grown spruce showing the dense mat of *Rosellinia* mycelium.

Figure 34. Perithecia of *Rosellinia*.

Rosellinia **blight**

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Douglas-fir, all spruces	1 + 0 2 + 0	Summer through fall	Yes	No	Yes	No

Sirococcus blight

This disease, caused by the fungus *Sirococcus strobilinus*, affects conifers throughout the North Temperate Zone, including all of British Columbia. Since being found on lodgepole pine seedlings at the Red Rock nursery in 1970, *Sirococcus* blight has appeared in nurseries throughout the province. It is more prevalent on container-grown than bareroot stock.

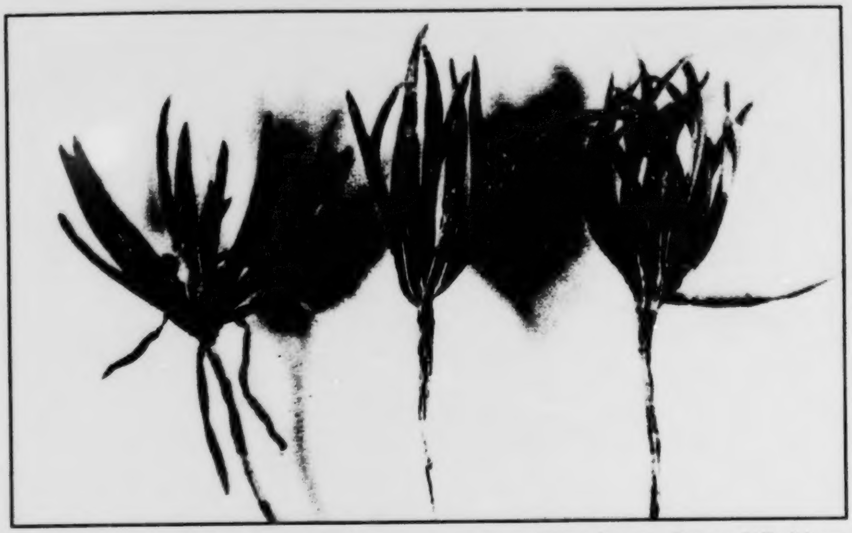
Figure 35. *Sirococcus* blight on container-grown spruce. Note that needles are killed from the base upward.

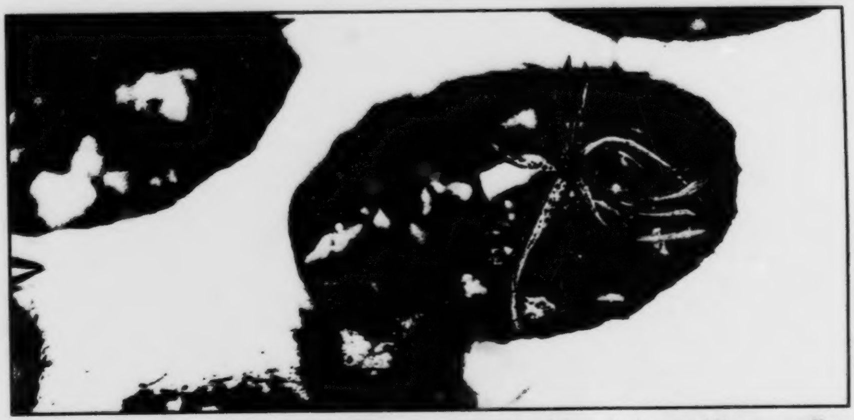
Figure 36. *Sirococcus* blight on container-grown spruce. Note dark pycnidia on needles.

Hosts and damage

Seedlings of Sitka, white and Engelmann spruce, lodgepole and ponderosa pine, Douglas-fir, and, very rarely, western hemlock are affected. On Douglas-fir the disease has been found only on bareroot seedlings. Disease symptoms and time of their appearance differ for container-grown and bareroot seedlings. Although 2-year-old, container-grown spruce are sometimes affected, *Sirococcus* most often attacks very young seedlings in container nurseries (Figures 35 and 36) where killing of the primary needles from the base upward is a common symptom.

Depending upon how far the disease has progressed, the upper portion of diseased needles may be green. Killed needles are light to reddish brown. Dead seedlings remain upright. Examining the base of diseased needles with a hand lens often reveals the small, irregularly rounded, light butterscotch-colored pycnidia (Figure 37); these darken with age. In container nurseries, the disease affects random seedlings (Figure 38), usually within specific seedlots because the pathogen is seed-borne. In germination tests, 1-2% of the spruce germinants often become diseased from seedborne inoculum. In container nurseries, mortality from secondary spread sometimes reaches 30% in some spruce seedlots.

In bareroot nurseries, symptoms usually appear in late summer through the fall on 1+0 bareroot seedlings or in the spring on 2+0 trees. The fall symptoms may be confused with early frost damage. Generally, the pattern of symptom development, color of diseased tissues, presence of pycnidia, and the random distribution of affected trees is the same as for container

Sirococcus blight

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All spruces	1 + 0 2 + 0	Spring and early summer	Yes	No	Yes	Yes
All hard pines	1 + 0 2 + 0	Late summer Fall through spring	Yes	Yes	Yes	Yes
Douglas-fir	1 + 0 2 + 0	Late summer Fall through spring	Yes	No	No	No

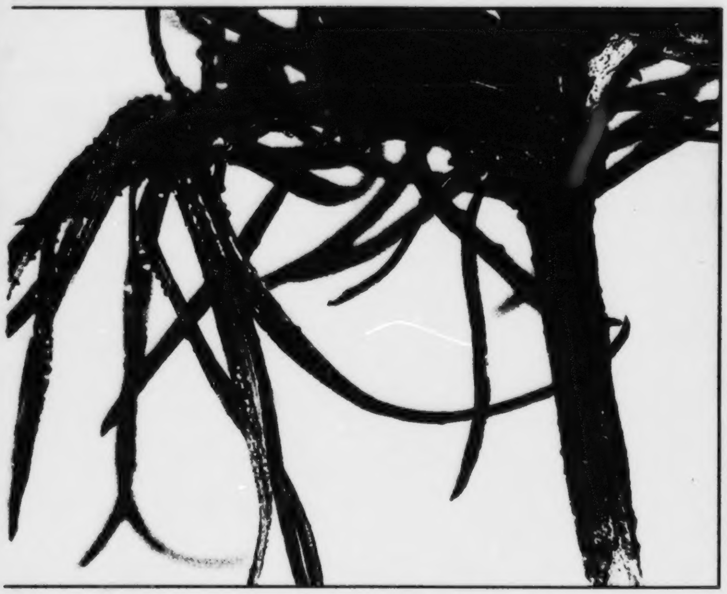

Figure 37. Pycnidia of *Sirococcus* on 2+0 lodgepole pine.

Figure 38. *Sirococcus* blight on container-grown lodgepole pine. Note how the disease spreads outward from a central point.

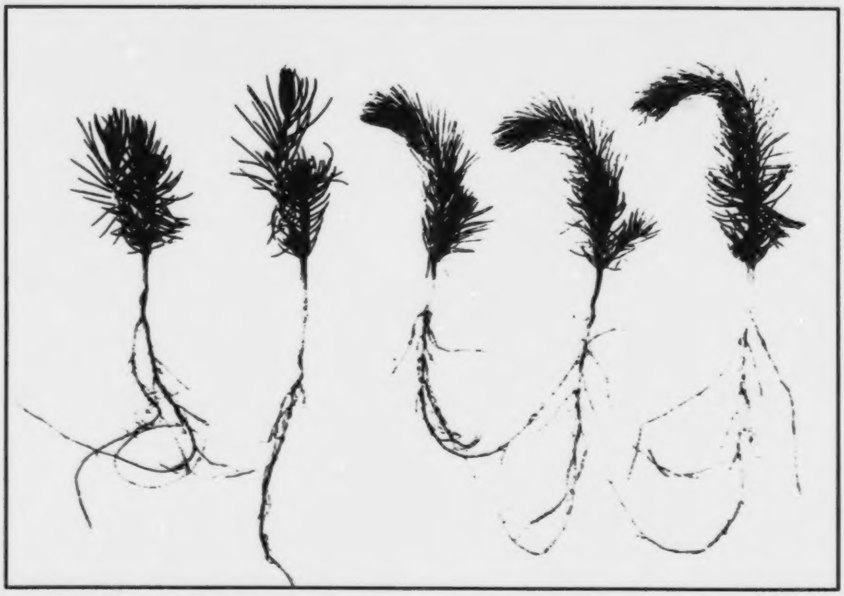

Figure 39. *Sirococcus* blight on bareroot spruce. Note that the leader was killed in the preceding year and a lateral has become dominant.

seedlings. The susceptibility of lodgepole pine varies among provenances. Whereas *Sirococcus* blight normally results in mortality of container-grown seedlings, it usually kills only part of the shoot on bareroot trees. A lateral branch then takes over as the terminal shoot (Figure 39). The desiccated terminal shoot of dead seedlings may assume a crozier-shape. In lodgepole pine, the pathogen's spread can often be traced from the primary needles, where infection may have occurred, to the base of the epicotyl and upward on the stem and secondary needles.

Life history (Figure 40)

Because *S. strobilinus* is seed-borne, initial disease centers in container nurseries develop from this inoculum and occasionally from spores from outside the nursery. The latter inoculum is probably most important in bareroot nurseries. Secondary spread is via pycnidiospores produced on diseased tissues and disseminated in rain and irrigation water. Infection occurs through young needles and is favored by cool, moist conditions and low light intensity, all of which often occur simultaneously in the spring and early summer in coastal British Columbia. This probably accounts for the higher *Sirococcus* incidence in coastal container nurseries. Because the pathogen has no other known spore forms, it is assumed that each new disease outbreak originates from seed- or wind-borne pycnidiospores. In California, diseased trees and cones (Figure 41) adjacent to nurseries are known "*Sirococcus* sources."

Management

Because infested seedlots are probably the major source of *Sirococcus* inoculum in container nurseries, records should be kept of all seedlots with blight history. When infested seedlots are sown, a fungicide should be applied as soon as symp-

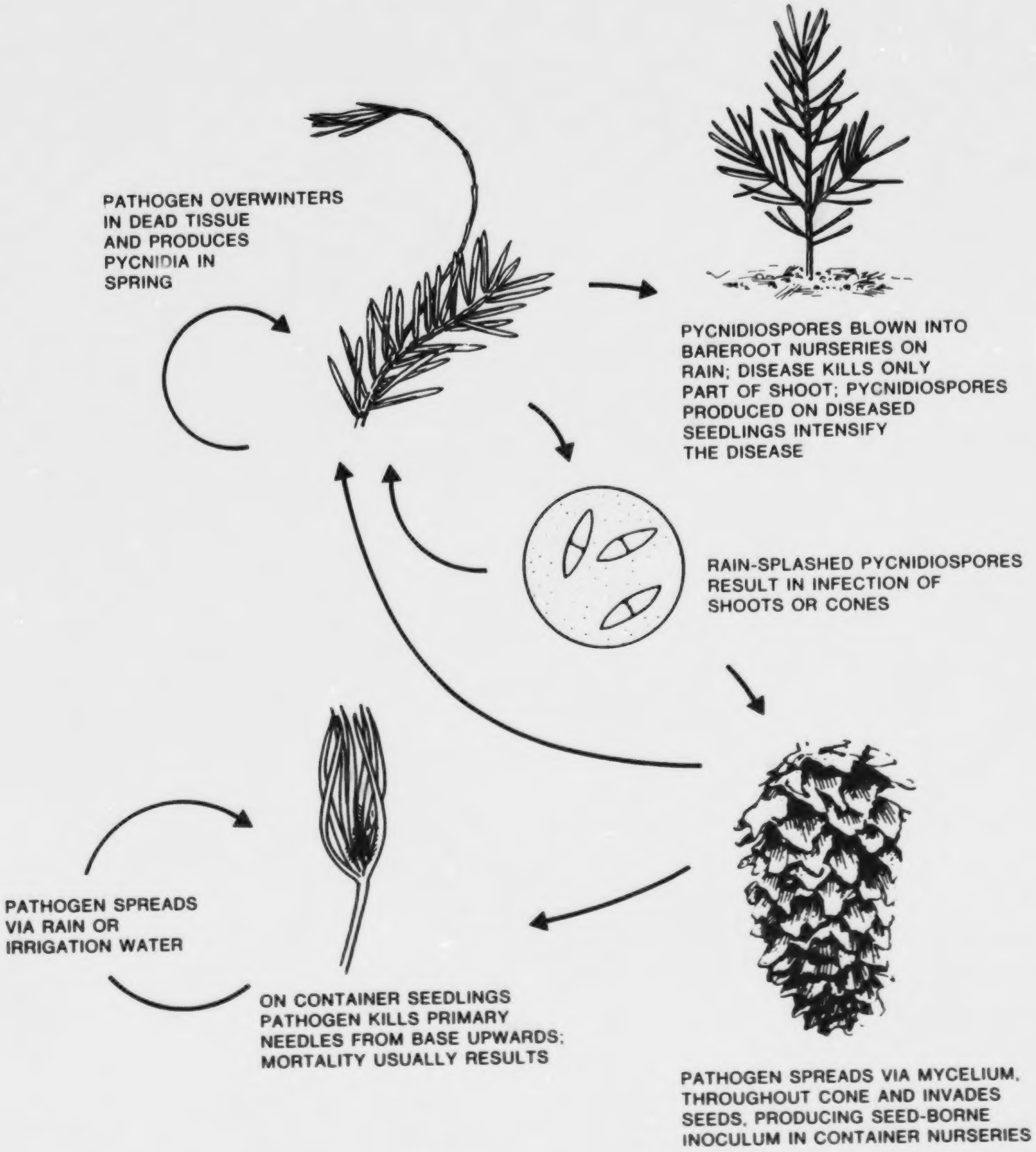
PATHOGEN OVERWINTERS IN DEAD TISSUE AND PRODUCES PYCNIDIA IN SPRING
PYCNIDIOSPORES BLOWN INTO BAREROOT NURSERIES ON RAIN; DISEASE KILLS ONLY PART OF SHOOT; PYCNIDIOSPORES PRODUCED ON DISEASED SEEDLINGS INTENSIFY THE DISEASE
RAIN-SPLASHED PYCNIDIOSPORES RESULT IN INFECTION OF SHOOTS OR CONES
PATHOGEN SPREADS VIA RAIN OR IRRIGATION WATER
ON CONTAINER SEEDLINGS PATHOGEN KILLS PRIMARY NEEDLES FROM BASE UPWARDS; MORTALITY USUALLY RESULTS
PATHOGEN SPREADS VIA MYCELIUM, THROUGHOUT CONE AND INVADES SEEDS, PRODUCING SEED-BORNE INOCULUM IN CONTAINER NURSERIES

Figure 40. Life history of *Sirococcus* blight.

toms appear, to prevent spread of the disease. Prudent use of fungicides will help prevent the subsequent development of fungicide-resistant strains of pathogenic fungi such as *Botrytis*. Diseased seedlings should be rogued and burned when practical. Disease spread can be alleviated by reducing humidity in greenhouses, and perhaps by increasing temperatures. Increasing illumination may be helpful, as light-stressed seedlings are most susceptible. Disease severity usually decreases with the advent of bright, warm growing conditions. Bareroot seedlings should be sprayed with the appropriate fungicide when the disease first appears.

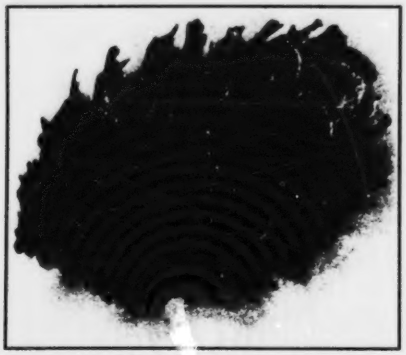

Figure 41. Pycnidia of *Sirococcus* on a Sitka spruce cone.

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Moulding of stored seedlings

Moulding of seedlings in storage has become a major problem in British Columbia because of the growing length in storage periods. The need for longer storage has occurred primarily because the recent increase in seedling production has prevented the lifting and shipment of all trees precisely when they are needed for outplanting; and the greater demand for high elevation provenances often means storing the stock until snow melt is complete in late spring. Another contributing factor has been the increased production of container-grown stock, which may contain incipient gray mould that can develop further in storage. Moulding of stored seedlings is a concern because stored trees are the nurseryman's final product, and they are at their maximum pre-shipping value.

Hosts and damage

Moulding of bareroot seedlings affects all species, although pines apparently less so than others. Initial evidence (Figure 42) of the disease includes cottony, mould on the lower needles, especially on seedlings within the storage bundles. These symptoms gradually progress upward on the shoots. Mould may be most noticeable around string holding seedlings in bundles. As the disease moves upward, stems and needles become watery and decayed, and affected needles fall off. Sometimes, after prolonged storage, moulding appears at numerous points scattered over entire seedlings.

Other symptoms that may appear on all or part of the stem and branches include water-soaked lesions, bark that strips off easily, and dead, butterscotch-colored cambium. Bundles of diseased seedlings may emit a musty odor and small clouds of mould spores. Symptoms can appear any time after storage begins, but usually the amount and probability of damage occurring are proportional to the length of the storage period. Sometimes mycorrhizal fungi proliferate on roots of stored seedlings, but they should not be confused with storage moulds that rarely occur on roots

The moulding of stored container-grown seedlings differs from that of stored bareroot seedlings in that only one or two fungi are involved (i.e., usually the gray mould pathogen *Botrytis cinerea* and sometimes *Rosellinia*). These fungi can become established during the growing season and continue to develop after the seedlings are stored. Hosts, symptoms, and damage of these diseases are described in separate chapters. Certain root fungi such as *Cylindrocarpon* and *Fusarium*, can be acquired by container-grown seedlings in the nursery and carried over into storage; see earlier sections on these diseases.

To date, in British Columbia, the amount of moulding damage on either bareroot or container-grown seedlings has not been correlated with subsequent outplanting survival. However, trees with advanced stem and branch decay and defoliation (Figure 43) probably survive poorly, and seedlings with low to moderate damage may be more affected by site, weather, and other factors than would healthy seedlings.

Life history[3]

Fungi such as *Fusarium, Rhizopus, Aspergillus, Penicillium, Epicoccum, Cylindrocarpon*, and numerous non-sporulating forms, are common on mouldy bareroot stock. Ordinarily, they live on dead or dying organic matter and only become

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[3] Because of the variation in the life histories of the pathogens involved, a diagram is not included here.

Moulding of stored seedlings

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species, pines least affected	1 + 0 2 + 0	When stored	Yes	Yes	Yes	Yes

pathogenic under favorable conditions. These fungi are ubiquitous, thus inoculum is on foliage prior to storage, in soil particles deposited onto shoots during lifting, or in soil adhering to seedling roots. None of these fungi occurring on bareroot seedlings have any specialized spores for survival, reproduction, or inoculation related specifically to their role in moulding.

Management

Storage moulds of both container and bareroot-grown seedlings are better prevented than controlled. Some practices that help reduce losses include: (i) storing stock for the shortest period possible, (ii) periodically examining a sample of each stored seedlot, and (iii) immediately shipping stock with initial moulding. The latter should receive special care to prevent further moulding in transit and prior to outplanting.

Seedlots containing significant quantities of dead organic matter (e.g., frost-killed or fertilizer-burned foliage) should be monitored closely because moulding fungi become established on this material before moving to healthy tissues. Transplants are very prone to moulding, especially if they have been lifted and stored as 2+0 stock – not shipped, transplanted late, then lifted and re-stored as 2+1 transplants. Such seedlings are likely to be in a weakened condition and thus more susceptible to moulding.

There is some evidence that moulding risk decreases as seedling frost hardiness increases. The best control for storage mould on container seedlings is to prevent establishment of gray mould or *Rosellinia* blight on the stock prior to storage. Infested stock should be inspected frequently once it is stored. Storing seedlings at 1-2°C reduces damage by severely limiting growth of most storage moulds. Their growth can be completely stopped by dropping the storage temperature to -2 to -3°C. Storing stock at these temperatures provides excellent control for stock that can withstand frozen storage. To date, species originating from the Interior seem best suited to sub-freezing storage. Frozen stock is usually thawed gradually, thus it should be watched closely for mould development during thawing and also afterward during shipping and prior to outplanting.

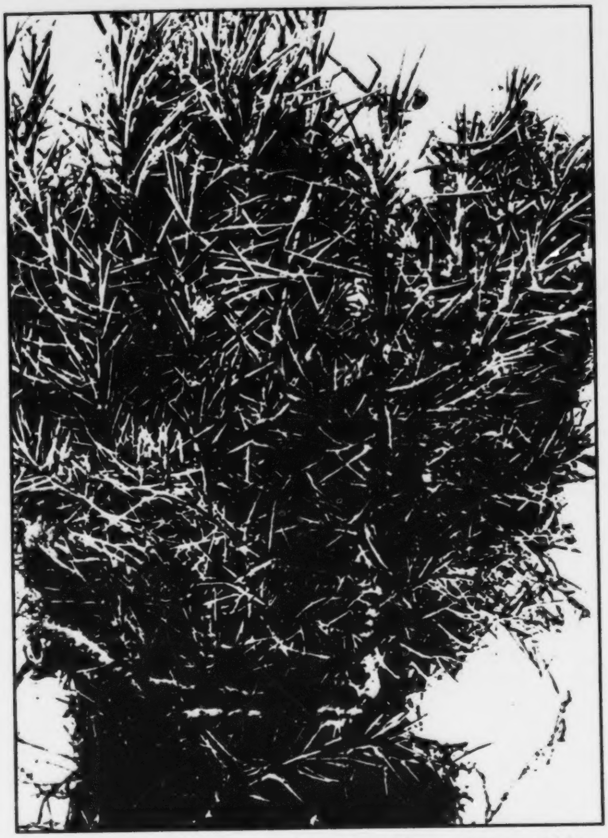

Figure 42. Bareroot Douglas-fir affected by storage moulding.

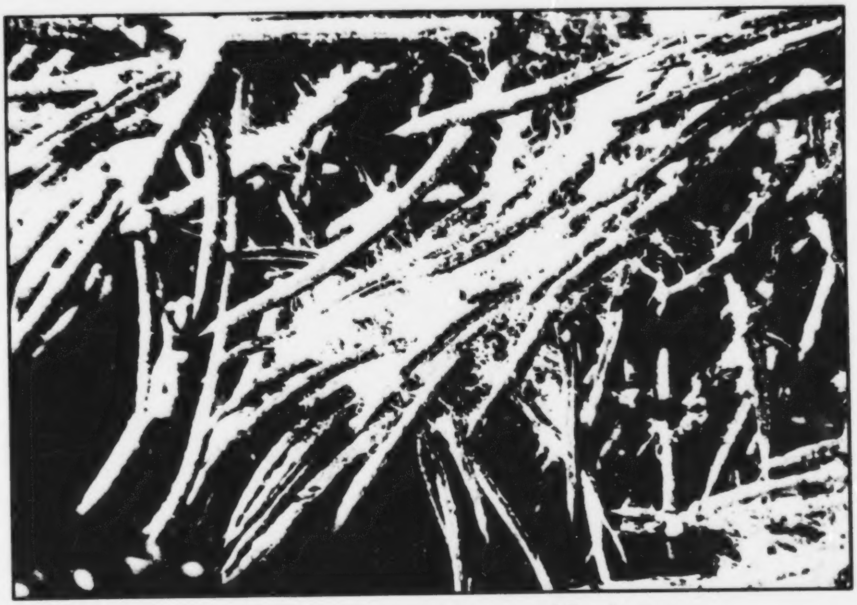

Figure 43. Foliage showing advanced symptoms of moulding in storage.

Most attempts at fungicidal control of storage moulds have involved either systemic or protective fungicides, or both at various pre-storage intervals. However, the results, especially with the protectants, have been erratic. Removing trees from storage, dipping them in fungicide, and restoring them is not recommended because it is too time-consuming, expensive, and potentially hazardous to nursery workers.

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Phomopsis canker and foliage blight

In British Columbia nurseries, *Phomopsis occulta* (perfect state = *Diaporthe conorum*) and *P. lokoyae* (perfect state = *D. lokoyae*) occasionally cause cankers and foliage blight.

Hosts and damage

These two fungi are widely distributed, occurring on many conifers, particularly western larch and spruces. Needle loss and shoot blight (Figure 44) can occur on 1+0 and 2+0 seedlings. Older seedlings may develop stem or branch cankers resulting in dieback of laterals, seedling death, or culling due to terminal shoot death. Cankers appear to be sunken, because of the growth of healthy tissue surrounding the dead tissue. Foliage and branches distal to the infection become yellow and die quickly. Sometimes seedlings die (Figure 45), but most losses are due to culling.

Life history (Figure 46)

These fungi are common saprophytes occurring on dead tissues of living seedlings, fallen cones, and dead stems and needles. *Phomopsis occulta* may be seedborne on western larch. Cankers form on young stems and branches of winter-dormant seedlings and grow for one season. If the stem is not girdled, lesions eventually heal and no permanent damage results. Small, black spherical pycnidia develop in cankers during spring or summer, producing spores that are spread by rain or irrigation water. Under favorable conditions, spores germinate on young branches or stems in late summer and infection results. The fungus moves through the bark to the cambium where it develops during the winter. The fungus' perfect state may occur in the fall on infected branches, releasing wind-borne spores that lead to within-nursery spread of the fungus.

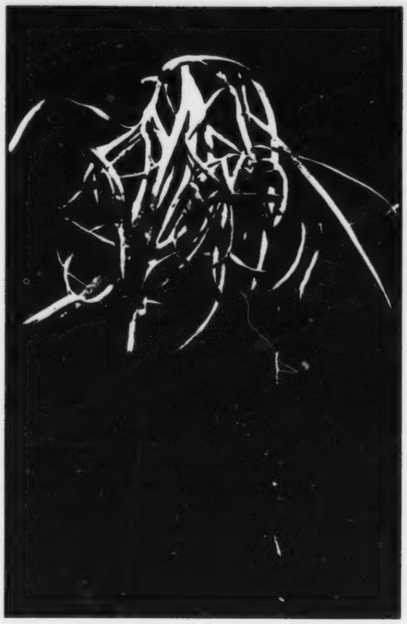

Figure 44. *Phomopsis* blight on western larch.

Management

Several cultural practices are important in *Phomopsis* management. Thinning seedlings and decreasing watering reduces humidity. Removing diseased seedlings decreases the amount of inoculum for spread of the fungus. Top pruning, which creates infection courts, should be avoided and stressed seedlings (e.g., from drought or frost) should be kept under careful surveillance as they are prone to infection. Under extreme conditions, applying a fungicide regularly to protect new growth from the time of germinant emergence through the fall has also proven to be effective.

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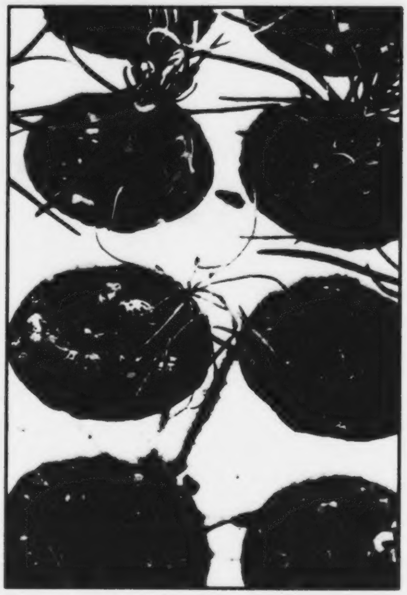

Figure 45. Container-grown western larch killed by *Phomopsis* blight.

Phomopsis canker and foliage blight

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All spruces	2 + 0	Spring through summer	Yes	Yes	Yes	Yes
Western larch, sometimes other species	1 + 0 2 + 0	Spring through summer	No	No	Yes	Yes

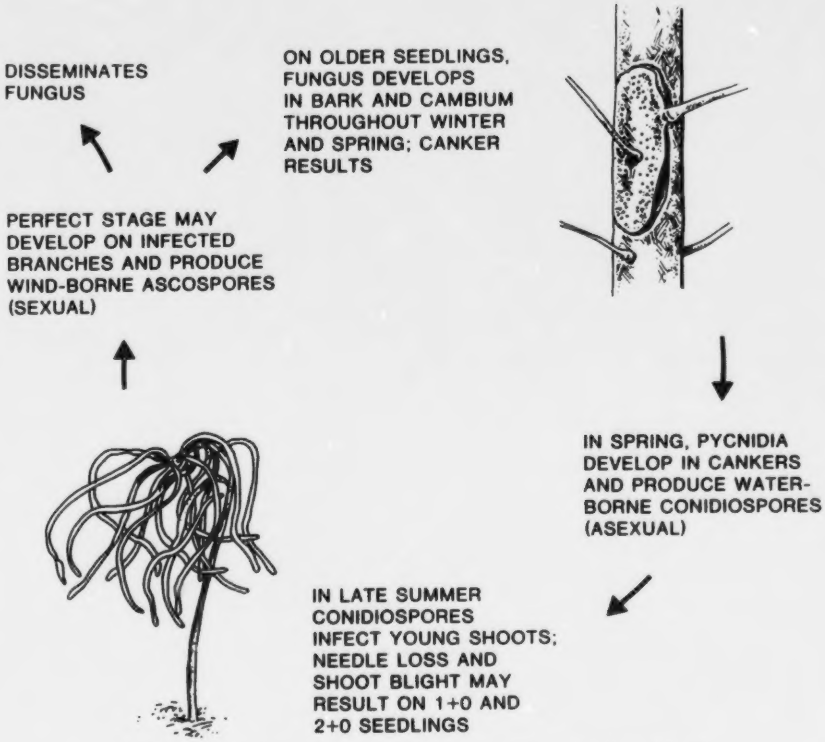
DISSEMINATES FUNGUS
ON OLDER SEEDLINGS, FUNGUS DEVELOPS IN BARK AND CAMBIUM THROUGHOUT WINTER AND SPRING; CANKER RESULTS
PERFECT STAGE MAY DEVELOP ON INFECTED BRANCHES AND PRODUCE WIND-BORNE ASCOSPORES (SEXUAL)
IN SPRING, PYCNIDIA DEVELOP IN CANKERS AND PRODUCE WATER-BORNE CONIDIOSPORES (ASEXUAL)
IN LATE SUMMER CONIDIOSPORES INFECT YOUNG SHOOTS; NEEDLE LOSS AND SHOOT BLIGHT MAY RESULT ON 1+0 AND 2+0 SEEDLINGS

Figure 46. Life history of *Phomopsis* canker and foliage blight.

***Melampsora* foliage rusts**

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Douglas-fir, all hard pines, all larches	1 + 0 2 + 0	Early to mid-summer	Yes	Yes	Yes	Yes

Melampsora foliage rusts

Only two foliage rusts occur in British Columbia forest nurseries: conifer-aspen rust (*Melampsora medusae*) and conifer-cottonwood rust (*M. occidentalis*). They derive their common names from the fact that they require at least one coniferous and one *Populus* spp. host to complete their life cycle. Since susceptible *Populus* are rarely grown in local forest nurseries, emphasis in this handbook is on how these diseases affect conifers. Both rusts occur predominantly in bareroot nurseries. Other foliage rusts, such as fir-willow rust (*M. abieti-capraearum*) and larch-willow rust (*M. paradoxa*), could be bothersome, especially if bareroot production of their coniferous hosts is increased.

Hosts and damage

Coniferous hosts for *M. medusae* are Douglas-fir, western larch, tamarack, and ponderosa and lodgepole pines; the *Populus* host is trembling aspen. Douglas-fir, black cottonwood, and balsam poplar are hosts for *M. occidentalis*. The rusts occur throughout the province wherever their hosts are present.

Both rusts produce yellow-orange, spore-producing pustules on foliage of their hosts (Figures 47-49). On coniferous needles or stems, these appear in late spring through mid-August and on *Populus* leaves in early summer to late fall. On the latter, the rust is most abundant on the underside of the leaf; corresponding chlorotic spots are present on the upper leaf surface. On conifers, symptoms are confined to the current year's foliage and often to the primary needles of rising 1+0 seedlings. Affected needles are usually killed and shed in the fall. Shoots of severely affected seedlings are killed. Disease intensity on individual seedlings and within nurseries is greatest near diseased *Populus* hosts. The scarcity of such trees near local nurseries probably accounts for the low level of *Melampsora* damage.

Life history (Figure 50)

Melampsora medusae and *M. occidentalis* both require their *Populus* and coniferous hosts to complete their life cycles. The rusts overwinter as teliospores on dead

Populus leaves on the ground. These spores germinate in the spring, producing windborne basidiospores, which results in infection of coniferous foliage. About 2 weeks later (late spring), masses of yellow-orange aeciospores are produced on needles of the coniferous host. They serve as inoculum for infection of live *Populus* leaves during the summer. Approximately another 2 weeks later, urediniospores (in yellow-orange pustules) are produced on the *Populus* leaves. These spores serve as inoculum for rust spread and intensification on *Populus* throughout the summer. In late summer, teliospores (the overwintering spores) are again produced on *Populus* leaves, completing the rust's life cycle.

Management

Elimination of *Populus* hosts in the immediate vicinity of conifer nurseries usually gives adequate disease control. When *Populus* cannot be eliminated, and where feasible, the fallen leaves can be raked and destroyed to eliminate the overwintering spores - i.e., the inoculum for coniferous seedlings. If neither of these procedures is practical, germinants and new growth of 2+0 seedlings can be protected with fungicidal sprays.

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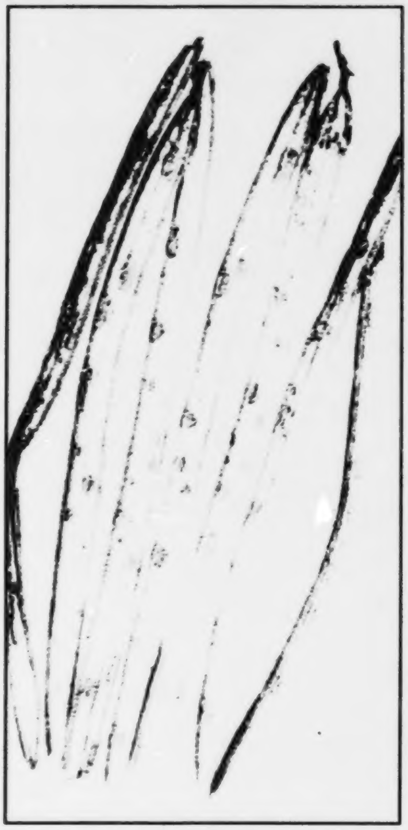


Figure 47. Aecia of *Melampsora occidentalis* on Douglas-fir needles.

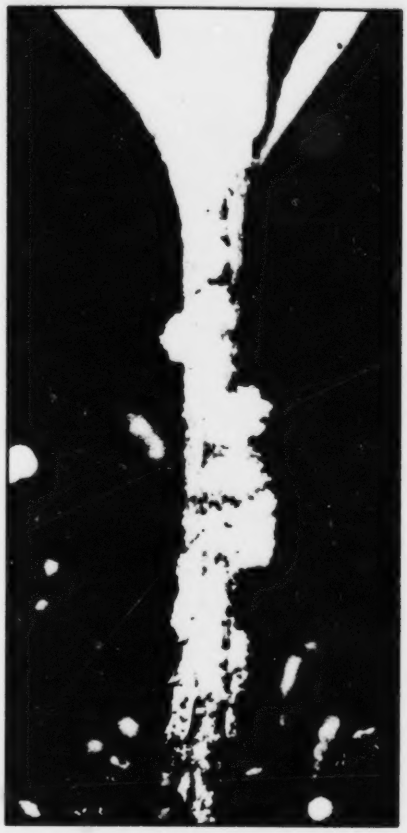


Figure 48. Aecia of *Melampsora medusae* on a lodgepole pine seedling.

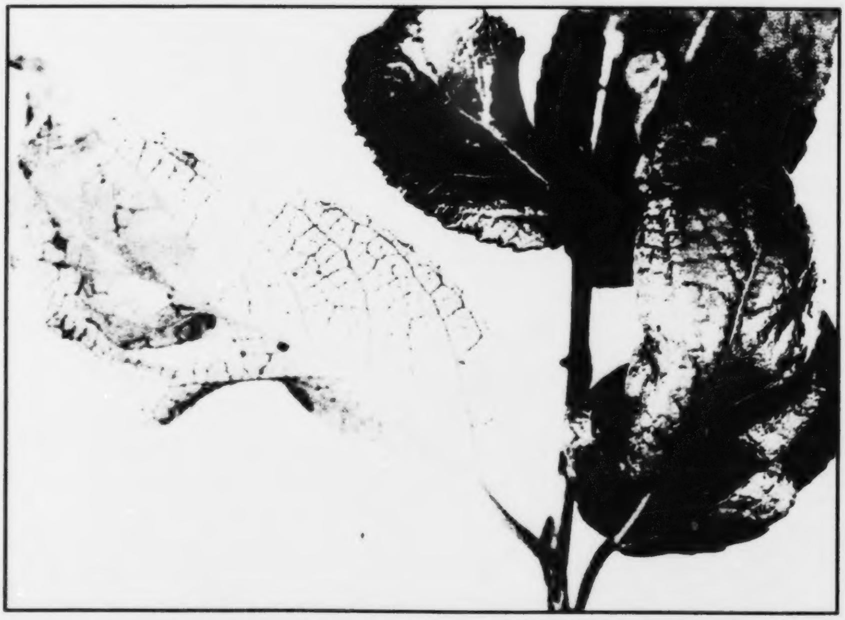


Figure 49. Uredinia of *Melampsora occidentalis* on black cottonwood leaves.

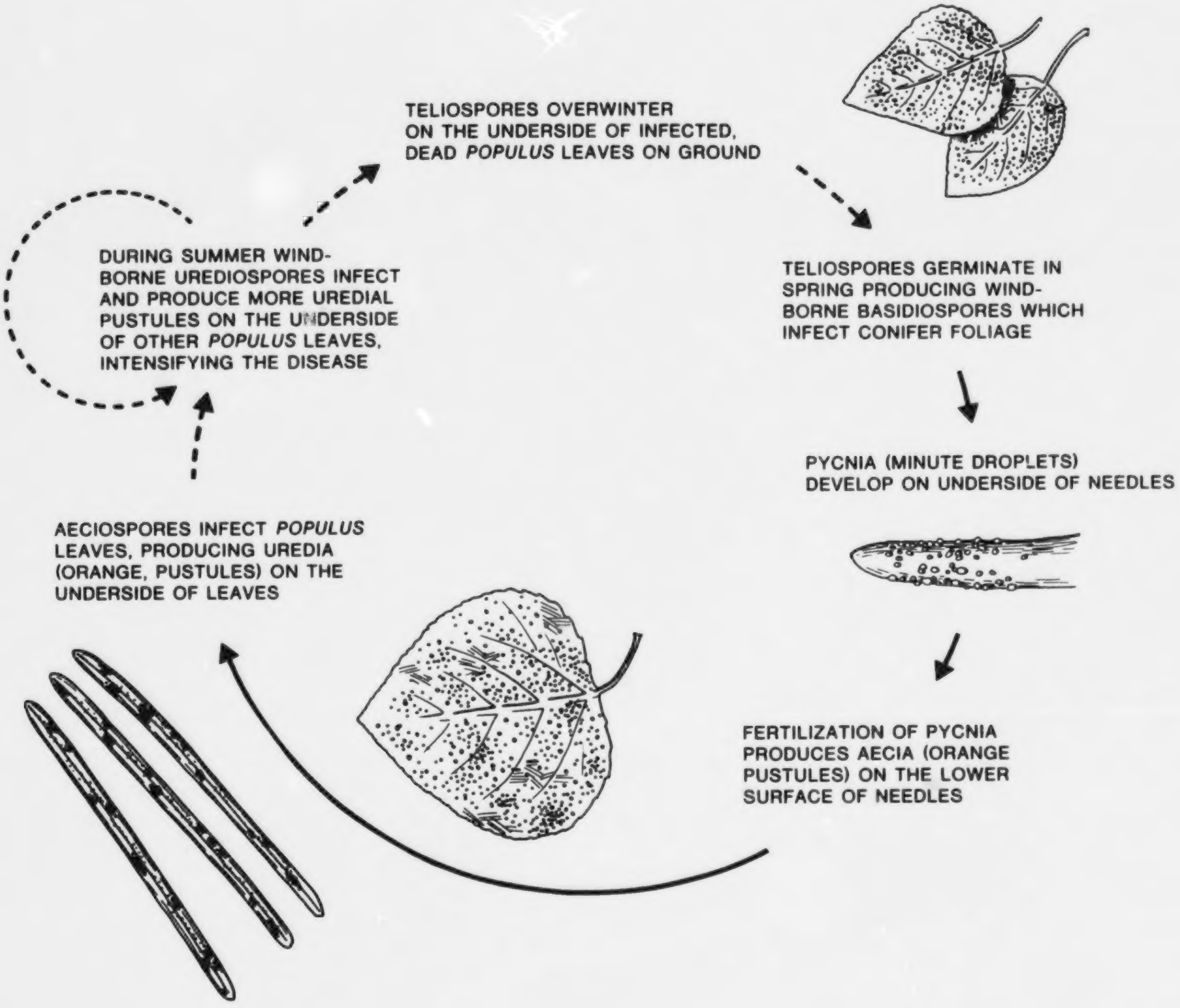

TELIOSPORES OVERWINTER ON THE UNDERSIDE OF INFECTED, DEAD *POPULUS* LEAVES ON GROUND
TELIOSPORES GERMINATE IN SPRING PRODUCING WIND-BORNE BASIDIOSPORES WHICH INFECT CONIFER FOLIAGE
PYCNIA (MINUTE DROPLETS) DEVELOP ON UNDERSIDE OF NEEDLES
FERTILIZATION OF PYCNIA PRODUCES AECIA (ORANGE PUSTULES) ON THE LOWER SURFACE OF NEEDLES
AECIOSPORES INFECT *POPULUS* LEAVES, PRODUCING UREDIA (ORANGE, PUSTULES) ON THE UNDERSIDE OF LEAVES
DURING SUMMER WIND-BORNE UREDIOSPORES INFECT AND PRODUCE MORE UREDIAL PUSTULES ON THE UNDERSIDE OF OTHER *POPULUS* LEAVES, INTENSIFYING THE DISEASE

Figure 50. Life history of *Melampsora* foliage rusts.

Western gall rust

This disease is caused by the fungus *Endocronartium harknessii.* The term "rust" designates both the disease and causal fungus. To date, the rust has been found in most bareroot nurseries in British Columbia where its hosts are grown. Although recent disease losses have been small, infected nursery stock can disseminate the rust to disease-free areas. Infection of nursery seedlings often occurs on the main stem; thus, if diseased stock is outplanted, the gall continues expanding and the tree dies, or may suffer windbreakage.

Hosts and damage

Hosts are two- and three-needle (hard) pines, of which only lodgepole and ponderosa pines are grown locally. Since there is an interval between infection and development of conspicuous galls (Figure 51), the disease is rarely noticed on stock until late in the second growing season, or it may go undetected until the lifted trees are graded or after they are outplanted. Locally, in recent years, seldom more than 1%, and often none, of the stock has been affected. Since seedlings are not killed, the only direct losses are the culling of lifted stock. Because these losses have been inconsequential, the disease has been largely ignored; however, western gall rust epidemics are cyclical and the potential for serious losses always exists.

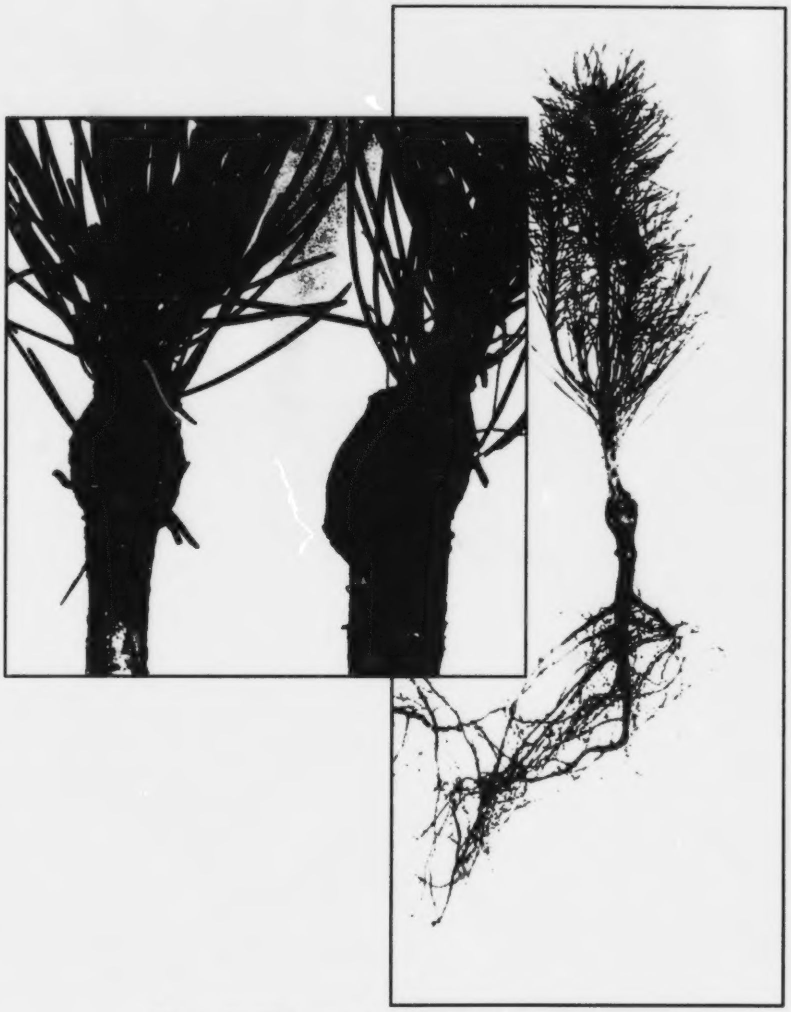


Figure 51. Western gall rust on 2+0 lodgepole pine.

Life history (Figure 52)

In spring and early summer, masses of orange-yellow spores are produced by and released from galls on diseased trees. When these wind-dispersed spores land on succulent current year's shoots or needles, they germinate – especially during rainy periods – and penetrate. The rust stimulates proliferation of the host's tissue so that 1.5-2 years later, irregular, rounded to pear-shaped swellings appear. These woody, perennial galls grow and release spores (Figure 53) annually, which can re-infect pines. Consequently, no alternate hosts are involved in this rust's life cycle. Eventually the stem or branch dies. Since the interval between infection and sporulation exceeds the usual period that most seedlings are in the nursery (except perhaps some transplants), there is no danger of disease spread among nursery seedlings. Instead, all inoculum originates from older infections on trees outside the nursery (Figure 54).

Because of the interval between infection and sporulation, it is obvious that (i) the galls seen on 2-year-old trees originate from infections occurring early in the first growing season, and (ii) trees infected during the 2nd year will be symptomless while in the nursery. The concern with these seedlings is that they mask the true incidence of the disease in the nursery, with the result that infected trees get outplanted unknowingly.

Western gall rust

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Lodgepole and ponderosa pines, other hard pines	2 + 0	Mid- to late summer	Yes	Yes	?	?

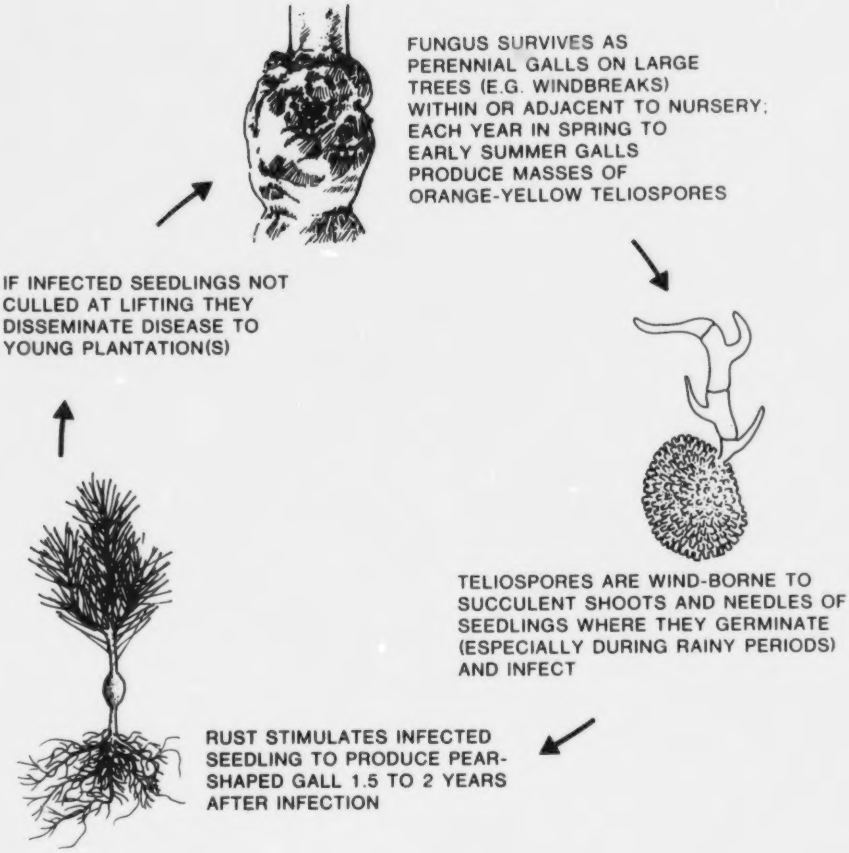

FUNGUS SURVIVES AS PERENNIAL GALLS ON LARGE TREES (E.G. WINDBREAKS) WITHIN OR ADJACENT TO NURSERY; EACH YEAR IN SPRING TO EARLY SUMMER GALLS PRODUCE MASSES OF ORANGE-YELLOW TELIOSPORES
TELIOSPORES ARE WIND-BORNE TO SUCCULENT SHOOTS AND NEEDLES OF SEEDLINGS WHERE THEY GERMINATE (ESPECIALLY DURING RAINY PERIODS) AND INFECT
RUST STIMULATES INFECTED SEEDLING TO PRODUCE PEAR-SHAPED GALL 1.5 TO 2 YEARS AFTER INFECTION
IF INFECTED SEEDLINGS NOT CULLED AT LIFTING THEY DISSEMINATE DISEASE TO YOUNG PLANTATION(S)

Figure 52. Life history of western gall rust.

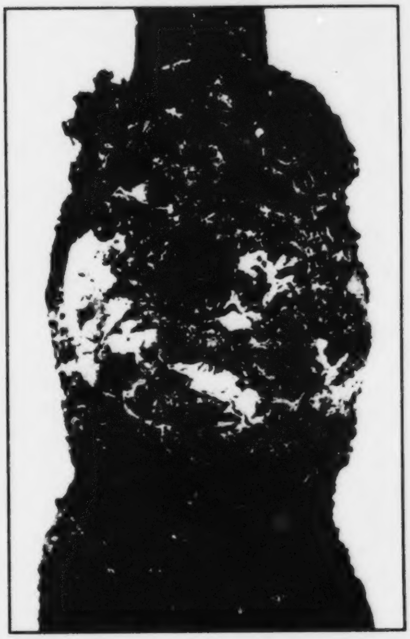


Figure 53. Western gall rust on 2+1 lodgepole pine. Note masses of spores which can vary in color from white to yellow.

Management

Because spores are blown into the nursery from outside, all gall rust infected pines should be cut for 275 m around the nursery. The unreliability of current prediction techniques makes fungicidal spraying of nursery seedlings impractical. Diseased seedlings should always be culled to lessen spread of the disease to new areas.

Selected References

Hiratsuka, Y. and J.M. Powell. 1976. Pine stem rusts of Canada. For. Tech. Rep. 4, Dep. Environ., Can. For. Serv., Ottawa, Ont.

Ziller, W.G. 1974. The tree rusts of western Canada. Dep. Environ.,Can. For. Serv., Publ. No. 1329, Ottawa, Ont.

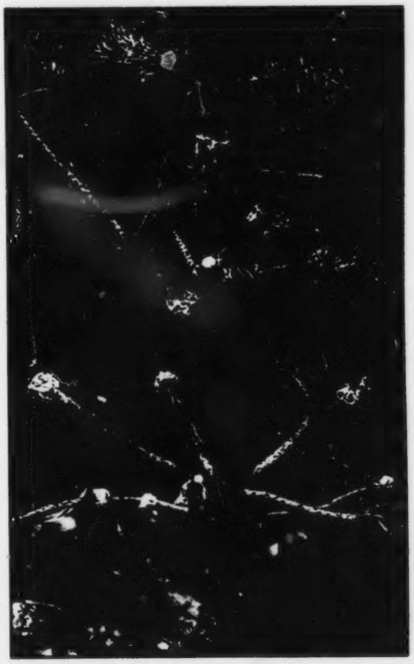


Figure 54. Globose galls on trees in windbreaks or adjacent to the nursery produce western gall rust inoculum (courtesy of Forest Insect and Disease Survey, P.F.C., Victoria, B.C.).

Colletotrichum blight

In the early 1980's *Colletotrichum acutatum* and *C. gloeosporioides* caused blights on container-grown western hemlock (Figure 55) in British Columbia. Experiments showed that *C. gloeosporioides* affects several conifers, especially western and mountain hemlock. *Colletotrichum* blights are favored by high humidity and temperature. Symptoms include blanching of young needles, progressing from bases upward, followed by affected needles becoming brown. Advanced symptoms include needle browning on the entire shoot, crooking of lateral branch and terminal shoot tips, and stem and needle lesions. The disease spreads from infection centers, quickly affecting all seedlings within large, circular areas.

Both fungi overwinter as mycelium, sclerotia, and perithecia in diseased host tissue on living plants or soil debris. Culling and destruction of infected seedlings are recommended. Because spore production, spread, and germination all require high humidity and free water, cultural practices that reduce moisture are important in managing the disease. Where possible (e.g., in greenhouses) temperature should be reduced. Often it is necessary to apply fungicide sprays in conjunction with these cultural practices.

Selected References

Griffin, M.S., J.R. Sutherland, and J.J. Dennis. 1987. Blight of conifer seedlings caused by *Colletotrichum gloeosporioides*. New Forests 1: 81-88.

Hopkins, J.C., W. Lock, and A. Funk. 1985. *Colletotrichum acutatum*, a new pathogen on western hemlock seedlings in British Columbia. Can. Plant Disease Surv. 65: 11-13.

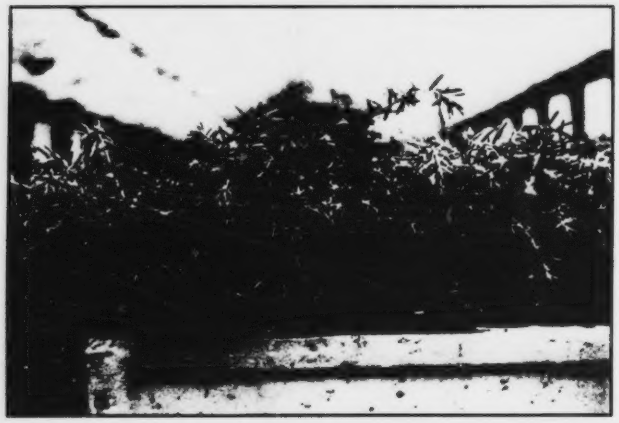


Figure 55. *Colletotrichum* blight on container-grown western hemlock.

Colletotrichum blight

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Western and mountain hemlock, other species susceptible	1 + 0	Summer	No	No	Yes	?

Fusarium top blight

Fusarium top blight, caused by *F. oxysporum*, can cause severe losses of 1+0 Douglas-fir and pines in bareroot and container nurseries. In containers, the problem is often traced to seed-borne inoculum. Bareroot inoculum carries over on bits of old roots and organic matter, including sawdust mulch. On germinants, rot appears at the junction of the seedcoat and cotyledons and spreads down the stem. Seedling mortality follows.

Both bareroot and container-grown seedlings are attacked from mid-to late growing season. Symptoms consist of purplish, then brownish discoloration near the base of the succulent terminal leader, the terminal bud, or adjoining needles. The pathogen progresses downward (Figure 56) killing all or part of the stem and the needles.

In bareroot culture, the disease is most likely to occur on seedlings in older nurseries with heavier soils, because the pathogen builds up over the years and heavy soils favor pathogen survival. Situating nurseries on lighter soils alleviates this problem. Bare fallowing and frequent cultivation of bareroot soils between crops also helps reduce inoculum. The practice

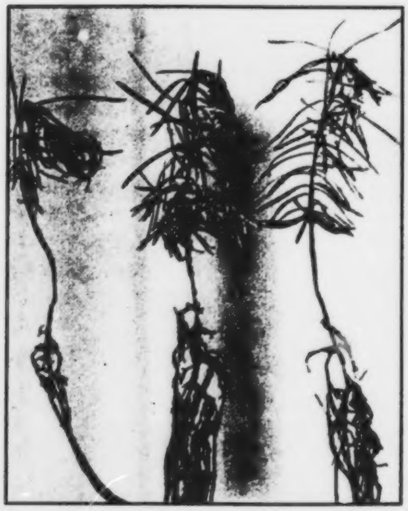


Figure 56. *Fusarium* top blight on container-grown Douglas-fir. In this case, inoculum was not seed-borne.

of roguing and culling diseased seedlings in both bareroot and container nurseries will help reduce pathogen spread. Fungicide sprays are sometimes used.

Selected References

Buckland, D.C. 1947. Investigations on the control of *Fusarium* top blight of Douglas-fir seedlings. Can. Dep. Agric., Victoria, B.C. Unpubl. rep.

Salisbury, P.J. 1951. Investigations on the control of damping-off and top-blight of Douglas-fir seedlings at the Duncan forest nursery in British Columbia in 1948 and 1949. Can. Dep. Agric., Victoria, B.C. Unpubl. rep.

Figure 57. *Fusarium* hypocotyl rot on a true fir seedling. Note masses of spores on stem.

Hypocotyl rot

Hypocotyl rot caused by *Fusarium* and *Phoma* species affects 1+0 Douglas-fir, lodgepole and ponderosa pine, and Engelmann and white spruce in container and bareroot nurseries. Although either of these fungi can cause the disease, they often occur together on seedlings. Laboratory assays are necessary to determine if one or both are causing the disease.

Initial symptoms include stunting, chlorosis, and wilting, followed by the development of a crook at the terminus of the leader, and death. Mortality occurs from July through October, affecting random seedlings throughout the nursery. Diseased seedlings are often predisposed by stress, such as drought.

The pathogen may also enter through wounded stem tissue (Figure 57). Inoculum may be seed-borne, wind-borne, or soil-borne. Bare fallowing in bareroot nurseries reduces pathogen populations. Early sowing may enable seedlings to mature and reach a more resistant stage before environmental conditions favor the disease. Using practices such as regulating watering, or mulch application, which prevent soil moisture stress and high soil temperatures, may alleviate disease losses. Although seldom warranted, fungicide drenches can begin after seedling emergence, but effectiveness varies with environmental conditions and cultural practices.

Selected References

Hamm, P.B. and E.M. Hansen. 1986. Stem canker diseases of Douglas-fir in nurseries. *In* Proc: Combined Western For. Nursery Council and Intermountain Nursery Assoc. Meeting. 12-15 August 1986, Tumwater, Wash. U.S. For. Serv., Rocky Mtn. For. Range Exp. Stn. Gen. Tech. Rep. RM-137: 106-108.

Kanaskie, A. 1986. Management of the top blight disease complex. *In* Proc: Combined Western For. Nursery Council and Intermountain Nursery Assoc. Meeting. 12-15 August 1986, Tumwater, Wash. U.S. For. Serv., Rocky Mtn. For. Range Exp. Stn. Gen. Tech. Rep. RM-137: 115-121.

Hypocotyl rot

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Douglas-fir, hard pines, and all spruces	1 + 0	Summer through fall	Yes	Yes	Yes	Yes

***Fusarium* top blight**

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Douglas-fir and pines	1 + 0	Summer through fall	Yes	Yes	Yes	Yes

Needle dieback

Needle dieback, which primarily affects container-grown Douglas-fir seedlings, is not fully understood. Similar symptoms have occurred to a lesser extent on true fir, spruce, and western larch. Symptoms (Figure 58), which first appear when seedlings are 1-2 cm in height, include stunted root and shoot growth, needle chlorosis, twisting and wilting of shoot tips, and needle tip dieback. Distribution of affected seedlings within seedlots is patchy, but often the disease is more prevalent in individual batches of growing medium. Plants affected during germination and early growth stages rarely reach end-of-season growth standards. Seedlings affected later suffer some needle damage but few other effects.

Studies indicate that a complex of *Pythium* species in association with unfavorable cultural practices, such as high growing medium temperatures and imbalanced ammonium-to-nitrate ratios, may be associated with needle dieback. To date, little information is available on dieback management, but apparently growing medium sterilization reduces dieback incidence.

Selected References

Husted, L. and S. Barnes. 1988. Dieback of container-grown Douglas-fir seedlings. Canada-British Columbia Forest Resource Development Agreement draft report prepared for CIP Inc. 31 p.

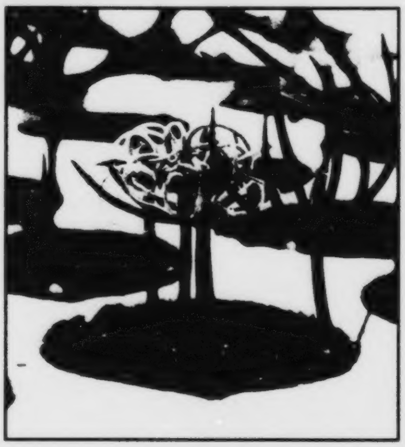


Figure 58. Needle dieback of Douglas-fir.

Phoma blight

Phoma species cause needle dieback on western hemlock, western redcedar, and several pine and spruce species in bareroot and, particularly, container nurseries (Figure 59). Cotyledons, lower needles, and buds are affected by this soil-borne fungus, resulting in defoliation. Infected needles become chlorotic, turn golden brown, and are cast. Other symptoms include dieback or tip blight which progress down the stem. Symptoms develop in the fall through early spring following the first growing season.

In bareroot seedbeds, cultural practices such as mulching, which reduces soil splashing, help reduce pathogen dispersal. Decreasing sowing densities improves air circulation and results in drier foliage, which inhibits the disease. Although *Phoma* losses in British Columbia have not justified soil fumigation, it has been used in western U.S. nurseries.

Selected References

Kliejunas, J.T., J.R. Allison, A.H. McCain, and R.S. Smith, Jr. 1985. *Phoma* blight on fir and Douglas-fir seedlings in a California nursery. Plant Disease 69: 773-775.

James R.L. 1980. Engelmann spruce needle and twig blight at the Coeur d'Alene Nursery, Idaho. U.S. Dep. Agric. For. Serv., North. Reg. Rep. 80-21.

Needle dieback

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Most severe on Douglas-fir, possibly on true fir; spruce and western larch	1 + 0	Early spring through early summer	No	No	Yes	Yes

***Phoma* blight**

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All pines and spruces, western hemlock, and western redcedar	1 + 0 2 + 0	Fall through following spring	Yes	Yes	Yes	Yes

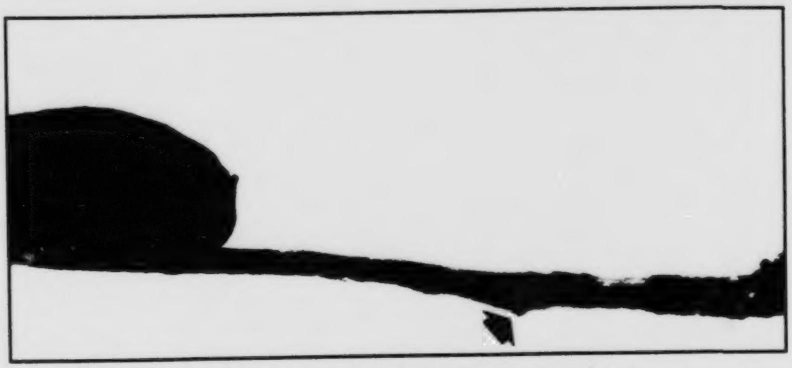


Figure 59. *Phoma* pycnidia (at arrow) on stem of spruce germinant.

Smothering fungus

The smothering fungus, *Thelephora terrestris*, is a mycorrhizal fungus associated with many coniferous species. It has a wide distribution and readily invades fumigated soils. It can occasionally grow up the stems of bareroot or container-grown seedlings, particularly where dense growth shades seedling bases. This habit gives it the name, "smothering fungus." The fruiting body of the fungus initially forms a collar around the lower stem and, in serious infestations, grows upward (Figure 60), smothering the seedling. It develops and matures on the seedling or surrounding surfaces such as styroblocks. The fungus does not rot tissue; however, severe smothering could result in mortality. Management practices that reduce humidity are important. These include growing seedlings at lower densities, carefully managing irrigation, and increasing ventilation in greenhouses.

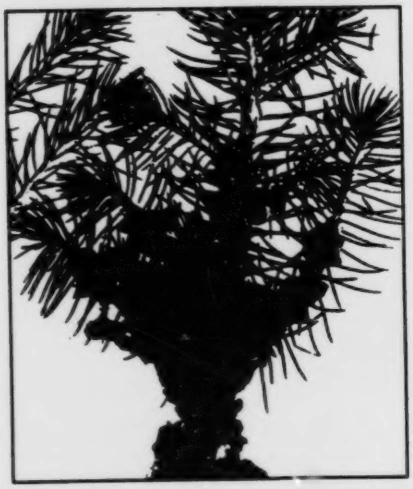


Figure 60. Smothering fungus on container-grown spruce.

Selected References

Hacskaylo, E. 1965. *Thelephora terrestris* and mycorrhizae of Virginia pine. For. Sci. 11: 401-404.

Zak, B. and D.H. Marx. 1964. Isolation of mycorrhizal fungi from roots of individual slash pines. For. Sci. 10: 214-222.

Smothering fungus

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	1 + 0 2 + 0	Throughout growing season	Yes	Yes	Yes	Yes

MINOR DISEASES IN BRITISH COLUMBIA FOREST SEEDLING NURSERIES

Pathogen (and disease caused)	Hosts	Type of nursery	Season	Remarks	Reference
Needle tip dieback *Alternaria* spp.	Engelmann spruce White spruce	Interior, container Coastal, container	Fall Winter	Could affect many hosts of all ages, in all nurseries, and throughout the year.	U.S. Dep. Agric. For. Serv. Nor. Reg. Rep. 87-9.
Shoot tip blight *Diplodia pinea*	Ponderosa pine	Interior, container	Summer	Other hosts possible, could affect seedlings of all ages in all nurseries.	Plant Dis. Rep. 60: 269-270.
Shoot blight *Pestalotia* spp.	Amabilis fir Larch	Coastal, bareroot Interior, container	Fall Summer	As above.	-
Root rot *Phytophthora* spp.	Douglas-fir	Interior, bareroot Coastal, bareroot	Summer Fall	Damage most prevalent in heavy saturated soils.	Plant Dis. 69:361.
Leader or branch dieback *Sclerophoma pithyophila*	Lodgepole pine Sitka spruce Douglas-fir	Interior, bareroot Coastal, container	Fall Summer	As for *Diplodia pinea*, usually affects stressed seedlings.	Plant Dis. Rep. 58: 94-95.

Insects Affecting Roots or Root Collar Area

Root weevils

Both the adults and larvae of root weevils can seriously damage seedlings, especially in coastal nurseries. Adults of the strawberry root weevil, *Otiorhynchus ovatus*, the rough strawberry root weevil, *Otiorhynchus rugosostriatus*, and the black vine weevil, *Otiorhynchus sulcatus*, all cause stem girdling. Less frequently, the small gray grass weevil, *Trachyphloeus bifoveolatus*, and *Strophosoma melanogrammus* girdle stems. Larvae of the strawberry root and black vine weevils are soil inhabitants. They feed on and seriously damage seedling roots (Figure 61). All root weevils have a similar general appearance and life history.

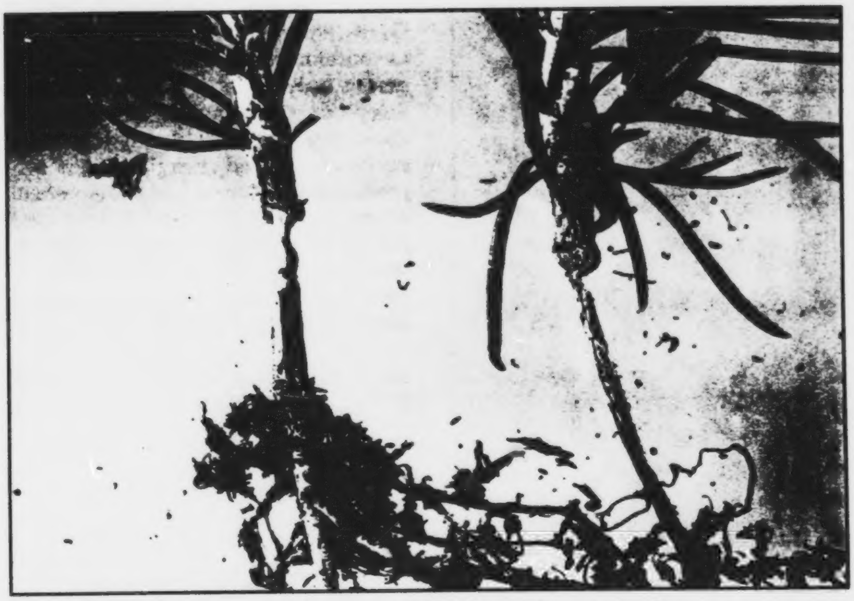


Figure 61. Container-grown 1+0 spruce girdled by adult root weevils.

Hosts and damage

Adult weevils primarily affect young 1+0 container seedlings growing in greenhouses. Spruce seedlings seem to be preferred, but cedar, hemlock, larch, true firs, and pine are also attacked. Stem girdling occurs in a band about 1 cm wide, usually on the fleshy, uppermost part of the hypocotyl, and may resemble damage by *Tehama bonifatella*. The latter differs by the presence of a fine silk webbing at the soil line. Feeding damage occurs primarily in June and July before stems become woody, when seedlings are approximately 8 weeks old and 8-15 cm in height; adult weevils feed all summer. Damaged seedlings often occur one at a time, near the outside edges of styroblocks and at the perimeter of greenhouses. Presence of weevils may go undetected because they feed at night and hide during the day.

Root weevils

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Larvae						
All species	1 + 0 2 + 0 Transplants	Late summer through fall	Yes	?	Yes	Yes
Adults						
All species, but prefer spruces	1 + 0	Early summer	?	?	Yes	Yes

Black vine weevil larvae mainly affect container stock in greenhouses, where high humidities provide favorable living conditions for larvae. To date, container nurseries in coastal areas have sustained the most damage; Douglas-fir and hemlock appear to be favored host species. Larvae can seriously damage grafted stock, which is frequently kept in heated greenhouses for several years, enabling weevils to reproduce year round, or where 2+0 container rotation allows population buildup over 2 years. Usually one larva (Figure 62) is found per container cavity as early instars are cannibalistic. Larvae feed throughout the fall and during warm periods in winter. One larva can consume

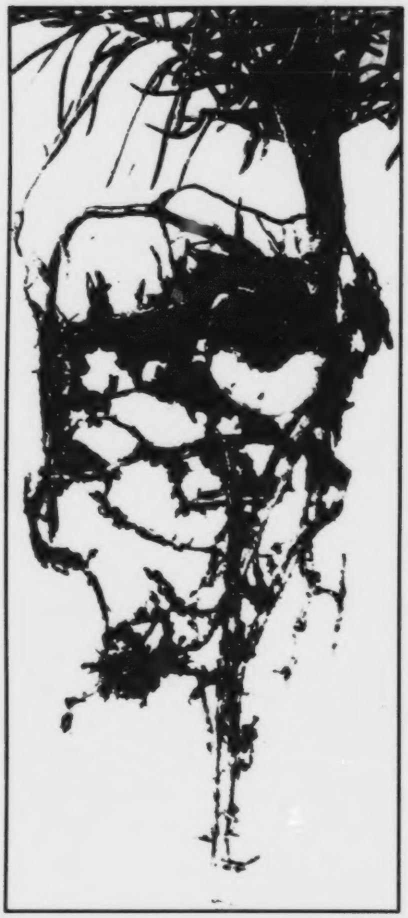


Figure 62. Black vine weevil larva on container-grown Douglas-fir.

almost all the roots of a seedling and may girdle the stem just below ground line. Damage often goes undetected, because the dormant seedlings exhibit no shoot symptoms in the winter. Thus, often neither the presence of the weevil nor damage is evident until the stock is lifted in the spring.

Although larvae of the strawberry root weevil are primarily a pest of strawberries, they can damage many species of 2+0 bareroot conifers. Most infestations occur at the edges of 2+0 panels, where larvae normally occur in patches. Larvae develop in the top 25 cm of soil around host plants and can number as many as 3000 per m^2. Larvae feed on the fibrous roots of seedlings, stripping most laterals and, in heavy infestations, girdling stems at the root collar (Figure 63). Again, damage may go unnoticed until seedlings are lifted, although seedlings may become chlorotic in the fall. Heavily damaged seedlings can be easily pulled from the soil. To date there has been no notable damage in 1+0 stock.

Life history (Figure 64)

The following generalized life history is based on outdoor, coastal conditions, where all weevil species pass through one generation per year; however, the timing and number of generations per year may be different in heated greenhouses. Overwintering occurs as larvae or adults. Oviposition by overwintered adults begins as early as May. Adults, which develop from overwintering larvae, appear about the end of May to early July. Both overwintering and emerging adults oviposit for about 7 weeks, and all oviposition ceases by early September. All adults are females, and generally egg-shaped, with short snouts, elbowed antennae, and stout, hard-shelled bodies. They are unable to fly (Figure 65).

Black vine weevil adults are 8-11 mm long and black with scattered patches of distinctive yellow hairs; strawberry root weevil adults are 4-6 mm long, and dark brown to black and slightly shiny. The rough strawberry root weevil is intermediate in size and generally a dark, chocolate-brown color. Eggs are laid mainly beneath duff, mulch, or the soil surface and have a 10- to 20-day incubation period. Larval size varies according to adult size (Figure 66). Larvae are slightly curved and creamy white with brown heads. They have no legs. Overwintering larvae pupate in earthen cells during the spring and early summer, emerging as summer adults.

Management

Weevil control is aimed at killing adults or preventing them from laying eggs. Larvae, once established, are difficult to control. In bareroot and container nurseries, surveys for adult weevils should be conducted during May and June when the majority are emerging. Detection of weevils is difficult, but may be done using bait stations or pit-fall traps. Broad leaved plants such as rhododendrons and azaleas, which are preferred hosts for weevils, can also be used for weevil detection. Growers may detect weevil presence by watching for damage on potted specimens of these plants placed around the nursery site. Signs of fresh girdling on conifer seedlings in June and July will also indicate that weevils are present and actively feeding. If not managed, these adults will likely oviposit on the stock.

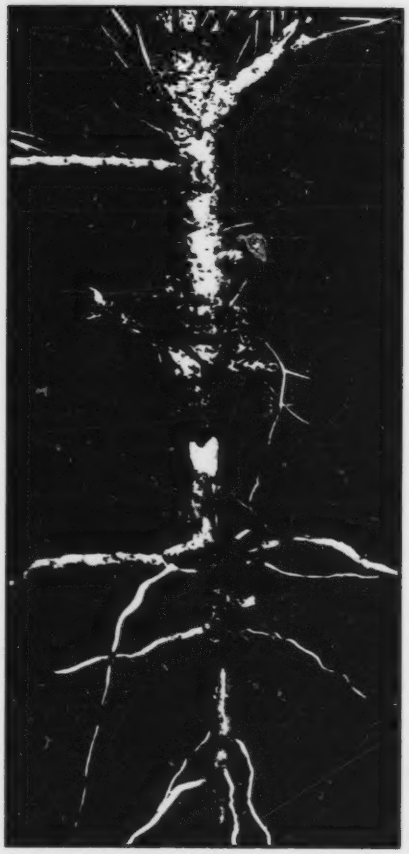


Figure 63. Strawberry root weevil girdling of bareroot spruce.

In bareroot nurseries, weevil boards have been used successfully to determine the length of the adult emergence period, the distribution of weevils in the nursery, and the effectiveness of control programs. A weevil board consists of a 30-cm length of a "two-by-four" which has been flagged with tape, numbered, and placed flat on the soil surface. These simple traps work because adult weevils feed on foliage at night and seek a cool, dark hiding place during the day. Best results are obtained when boards are placed in open areas because they provide an only source of shelter for weevils. More weevils are caught in 1+0 and fallow panels, than in 2+0 panels.

If surveys detect adult weevils, or if nurseries experienced serious problems with them during the previous growing season, control is advisable. Insecticidal sprays should be applied around the end of May - i.e. as soon as adults become active. A second application about 4 weeks later will control late-emerging adults before they oviposit. Disking bareroot panels in April and May will kill fragile pupae. Removing weeds, which act as reservoirs for adults, will help lower endemic weevil populations.

Selected References

Garth, G.S. and C.H. Shanks, Jr. 1978. Some factors affecting infestation of strawberry fields by the black vine weevil in Western Washington. J. Econ. Entomol. 71: 443-448.

Gerber, H.S., N.V. Tonks, and D.A. Ross. 1974. The recognition and life history of the major insect and mite pests of ornamental shrubs and shade trees of British Columbia. B.C. Dep. Agric., Bull. 74-13, Victoria, B.C.

Nielsen, D.G., M.J. Dunlap, and J.F. Boggs. 1978. Controlling black vine weevils. Amer. Nurseryman 147: 12, 13, 89-92.

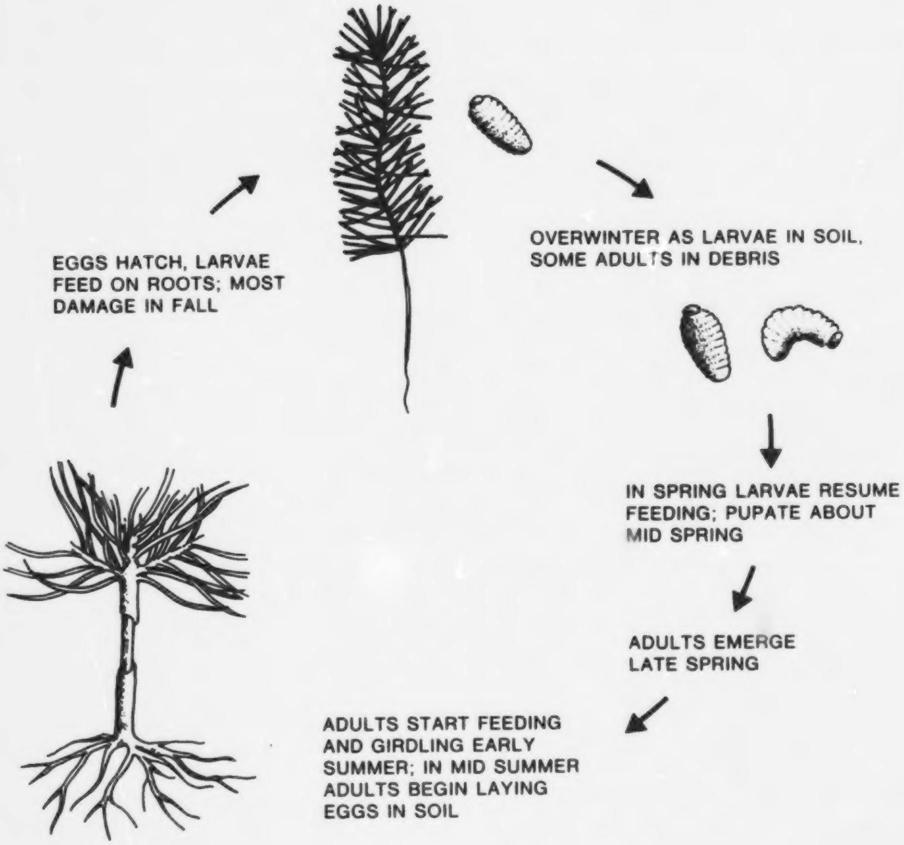
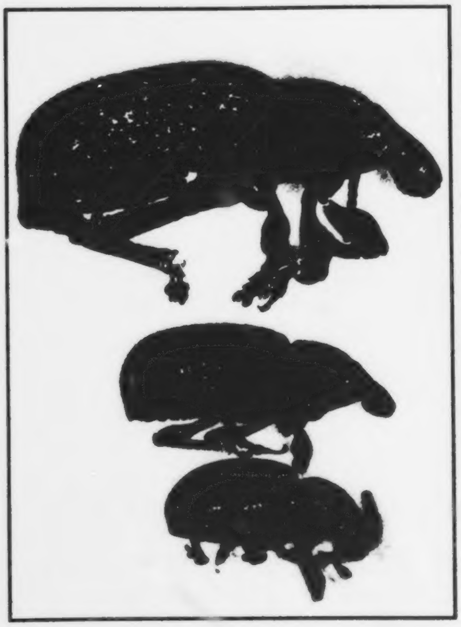

OVERWINTER AS LARVAE IN SOIL, SOME ADULTS IN DEBRIS
IN SPRING LARVAE RESUME FEEDING; PUPATE ABOUT MID SPRING
ADULTS EMERGE LATE SPRING
ADULTS START FEEDING AND GIRDLING EARLY SUMMER; IN MID SUMMER ADULTS BEGIN LAYING EGGS IN SOIL
EGGS HATCH, LARVAE FEED ON ROOTS; MOST DAMAGE IN FALL

Figure 64. Life history of root weevils (one generation per year).



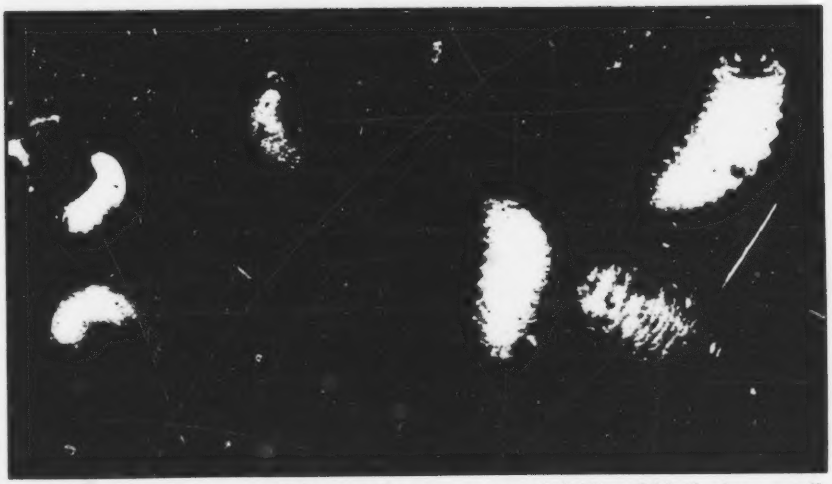


Figure 66. (above) Larvae of the strawberry root weevil (left) and black vine weevil. Note the larger size of the latter.

Figure 65. (left) Adults of the black vine weevil (top), rough strawberry root weevil (middle), and strawberry root weevil (lower). Note size and color differences.

Cranberry girdler

The cranberry girdler, *Chrysoteuchia topiaria*, was first identified as a pest in British Columbia in 1981. Pheromone traps have been used to confirm presence of adults at nurseries throughout the province. A related species, *Tehama bonifatella*, (previously called *Crambus nevadellus*), has recently been found girdling container seedlings. These two species are small, snouted moths (family Pyralidae) and are a common pest of grasses. Because the larvae produce a characteristic webbing at the feeding site, they are known as sod webworms.

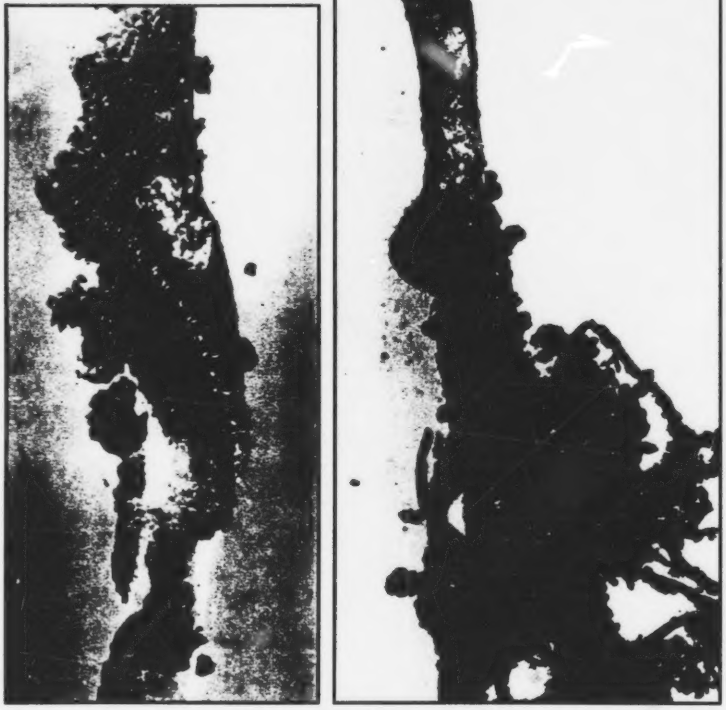


Figure 67. Cranberry girdler larvae and damage. Note ragged appearance of girdled bark.

Hosts and damage

Cranberry girdler larvae attack bareroot 2+0 Douglas-fir and true firs and 2+0 container Douglas-fir and spruce during their 2nd year. To date, susceptible bareroot species have been attacked at facilities across British Columbia, but container stock has only been affected at Interior nurseries.

Larvae (Figure 67) feed on the bark and chew into the wood of the stem, leaving a ragged appearance. They generally attack the stem area 2.5 cm above and below the soil line (Figure 68) with some feeding damage to the upper roots. Major damage causes seedlings to become chlorotic unless girdling takes place late in the season, but often damage is not noticed until seedlings are lifted. By this time, larvae have formed cocoons in the soil which are hard to locate and difficult to control. Damage occurs in patches due to the solitary feeding habit of the larvae. They feed on approximately five seedlings at one location, then travel about 50 cm before feeding again.

Tehama bonifatella larvae have attacked 2-year-old container spruce seedlings at several nurseries in the Okanagan. Damage appears as a uniform ring 1-2 cm wide just at the soil line, resembling adult root weevil girdling. It differs by the presence of fine silk webbing at the surface of the container cavity. Most damage occurs during August, but fresh girdling may be noticed as late as October. Damage occurs in small patches of 1-7 seedlings throughout the container nursery.

Life history (Figure 69)

The adult moths are small and delicate, 1-2 cm long, with a protruding snout. The forewings of the cranberry girdler moth

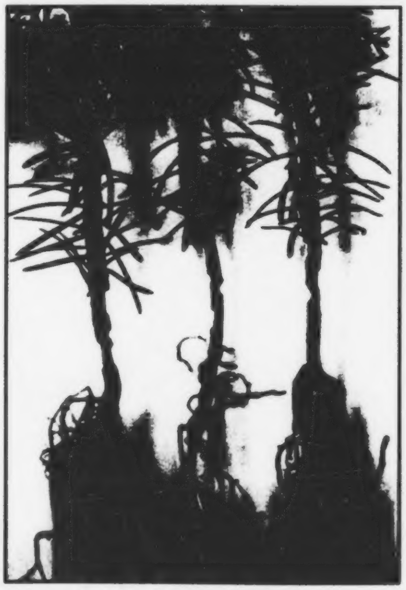


Figure 68. Cranberry girdler damage on container-grown Douglas-fir.

Cranberry girdler

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
True firs, Douglas-fir, and spruces	2 + 0	Late summer to fall	Yes	Yes	?	Yes

(Figure 70) are pale straw-colored, with touches of brown, silver, and black; the hind wings are silvery gray. *Tehama bonifatella* moths (Figure 71) have beige forewings with mottled brown markings and straw-colored hind wings. They are present from mid-June into July and lay up to 500 eggs each. Larvae hatch and live in the upper soil surface where they feed from late August to mid-November. Larvae are particularly attracted to sawdust placed on bareroot seedbeds to reduce frost heaving. Larvae are about 1.5 cm long, with a tan head capsule and dirty-white body covered with long and short hairs, black at the base and finely pointed.

Management

The use of pheromone traps to monitor moth populations, combined with a foliar spray program, has proven successful in the control of cranberry girdler moths. Traps are placed 30 m apart in bareroot nurseries and open compounds, and one per greenhouse from early June to mid-August. Peak moth flight occurs from mid-June to mid-July. When an average of three moths are caught per pheromone trap in 1 week, larvae-caused damage will be significant in the fall. If this number is reached in any week, a single insecticidal spray is recommended. This spray works partly as a repellant to moths and, through contact activity, kills moths that alight on foliage to lay eggs. Cultural practices such as the removal or frequent mowing of grasses surrounding the nursery can help reduce endemic populations.

Selected References

Tunnock, S. 1982. Cranberry girdler moth damage to Douglas-fir seedlings in Coeur d'Alene Nursery, Idaho Panhandle National Forests. U.S. Dep. Agric. For. Serv. North. Reg. Rep. 82-28.

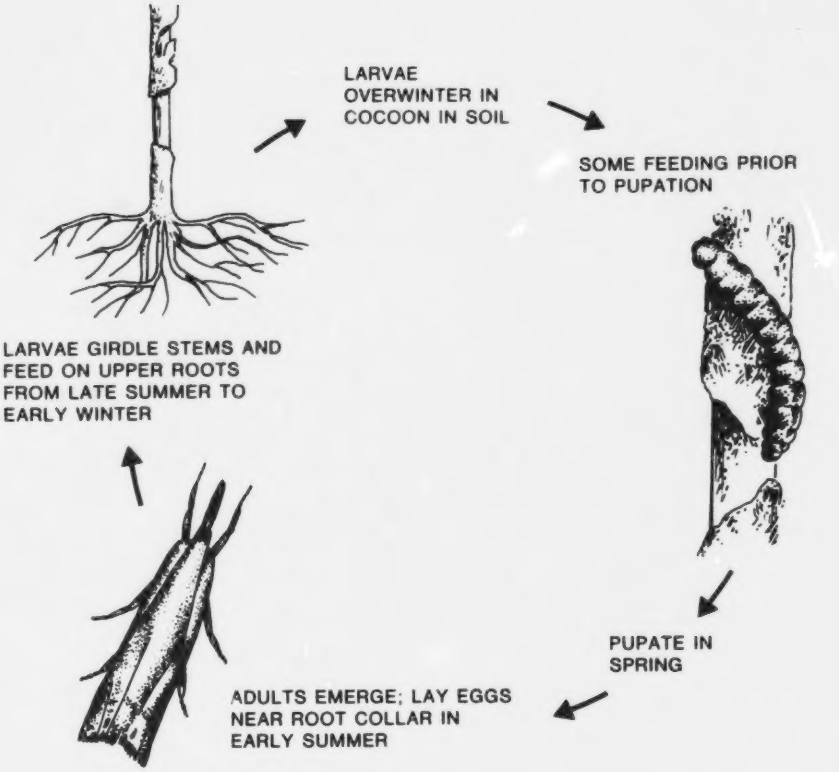

LARVAE OVERWINTER IN COCOON IN SOIL
SOME FEEDING PRIOR TO PUPATION
PUPATE IN SPRING
ADULTS EMERGE; LAY EGGS NEAR ROOT COLLAR IN EARLY SUMMER
LARVAE GIRDLE STEMS AND FEED ON UPPER ROOTS FROM LATE SUMMER TO EARLY WINTER

Figure 69. Life history of cranberry girdler (one generation per year).

Figure 70. Adult cranberry girdler.

Figure 71. *Tehama bonifatella*, larva and adult .

Fungus gnats

Larvae of fungus gnats, most commonly *Bradysia* species (family Sciaridae), can be a problem in container nurseries where populations may build up rapidly under favorable conditions. Although it is the larvae of fungus gnats which damage seedlings, adults are most conspicuous. They are small (2.5 mm), dark, mosquitoe-like flies, distinguishable from the often abundant shore flies (family Ephydridae) by clear wings, long legs and long segmented antennae (Figure 72). Adults run along the top of styroblocks or fly over seedlings, and although they do little direct damage, they have recently been shown to act as vectors for pathogenic fungi such as *Botrytis* and *Fusarium*.

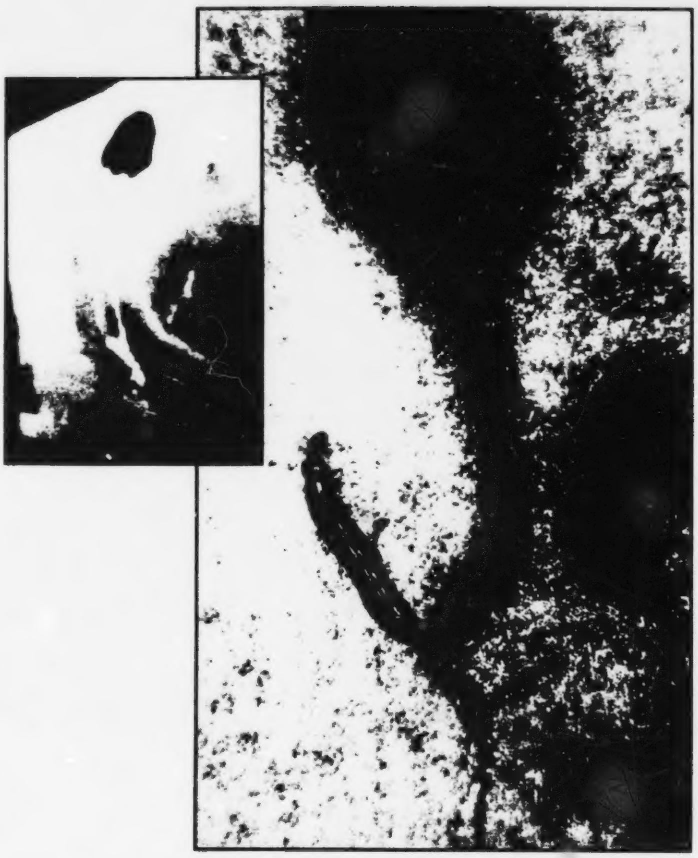


Figure 73. Fungus gnat larva with damaged spruce germinant. Note the larva's semi-transparent body and black head.

Hosts and damage

Fungus gnats breed and populations increase in container nurseries if algae, decaying organic matter, and moisture are abundant. Larvae infest container cavities with no apparent host preference. Although larvae generally feed on fungi and organic matter, they are attracted to seedling roots predisposed by stress, and often accompany the root pathogen *Fusarium*. They prefer to feed on the upper roots, consuming root hairs and small rootlets. In heavy infestations, fungus gnat larvae (Figure 73) will strip the main roots leaving only the vascular tissue, and will sometimes girdle entire stems. Seedling wilting and sudden loss of vigor results. Well-established and vigorously growing seedlings are usually unaffected by the larvae.

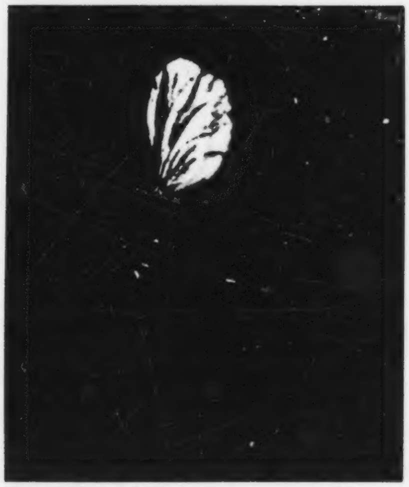


Figure 72. Adult fungus gnat (male).

Life history (Figure 74)

Under favorable conditions, fungus gnats complete their life cycle in 3 weeks, permitting rapid population build-up. Adults are attracted to moss and other organic matter on styroblocks or greenhouse floors, where they lay their eggs. Larvae emerge and are legless, semi-transparent, milky-white worms with black heads, reaching 5 mm in length.

Management

Sanitation and good drainage are the best methods of fungus gnat management. Keeping styroblocks, benches, and greenhouse floors free of mosses, algae, and excess water helps prevent population build-up. Producing vigorous healthy stock and avoiding over-watering makes seedlings less attractive. Population levels

Fungus gnats

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	1 + 0 2 + 0	Throughout growing season	No	No	Yes	Yes

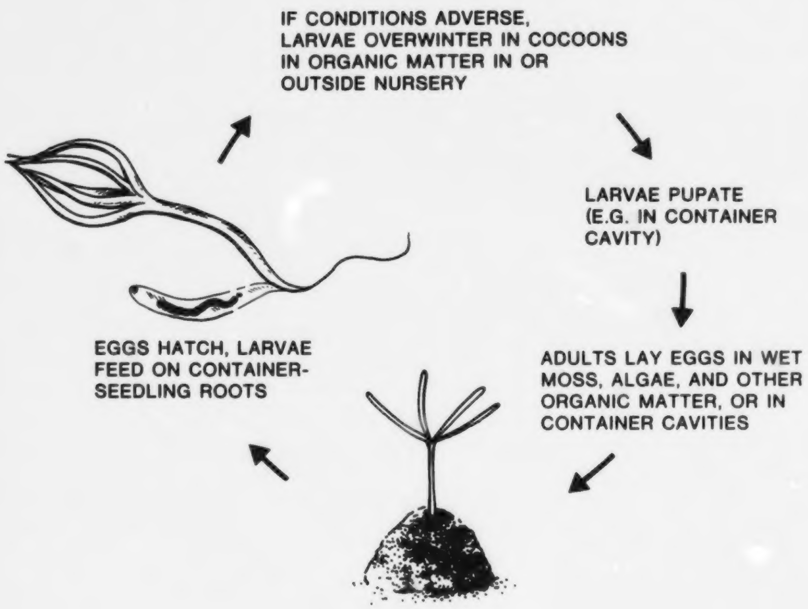

IF CONDITIONS ADVERSE, LARVAE OVERWINTER IN COCOONS IN ORGANIC MATTER IN OR OUTSIDE NURSERY
LARVAE PUPATE (E.G. IN CONTAINER CAVITY)
ADULTS LAY EGGS IN WET MOSS, ALGAE, AND OTHER ORGANIC MATTER, OR IN CONTAINER CAVITIES
EGGS HATCH, LARVAE FEED ON CONTAINER-SEEDLING ROOTS

Figure 74. Life history of fungus gnats (3-week life cycle; many generations per year).

Figure 75. Adult fungus gnats caught on a yellow sticky trap.

can be monitored with the use of yellow sticky traps (Figure 75). If fungus gnats persist and damage results, an insecticide drench may be necessary.

Selected References

Rutherford, T.A., D.B. Trotter, and J.M. Webster. 1985. Monitoring fungus gnats (Diptera: Sciaridae) in cucumber greenhouses. Can. Ent. 117: 1387-1394.

Shrimpton, G. 1983. Biology and control of some insect pests in B.C. Forest Service seedling nurseries. M.P.M. thesis. Simon Fraser Univ. Dep. Biol. Sci., Burnaby, B.C.

Wilkinson, J.D. and D.M. Daugherty. 1970. The biology and immature stages of *Bradysia impatiens* (Diptera: Sciaridae). Ann. Entomol. Soc. Amer. 63: 656-660.

European marsh crane fly (leatherjackets)

Larvae of the European marsh crane fly, *Tipula paludosa*, are known as leatherjackets because of their tough leather-like skin. This introduced pest was first found in British Columbia in Vancouver area lawns in 1965. For the past several years leatherjackets have been a problem for most coastal nurseries. Because of the susceptibility of the eggs and young larvae to desiccation, spread has been restricted to coastal areas in southern British Columbia and northern Washington.

Hosts and damage

Leatherjackets will attack seedlings of any species present on the nursery site in the spring. To date, most damage has been on 2+0 and transplant bareroot stock, but 2+0 container stock has also been attacked. If container seedlings are shipped as 1+0 stock, damage may go undetected. However, if larvae remain in the roots during winter lift they may damage outplanted seedlings in the spring. Leatherjackets girdle the stem (Figure 76) at the soil line, causing a uniform, 3-cm wide ring around the stem. They feed only on the bark and may strip some upper roots. Feeding occurs in spring, with damage having a spotty distribution with patches of one to seven seedlings.

Girdling prevents water transport to the shoot, which dries out, resulting in needle browning and eventual drop. Some feeding damage has been observed on needles of seedlings inside cold storage boxes.

Life history (Figure 77)

Under coastal British Columbia conditions, the marsh crane fly completes one generation per year, passing through egg, larva, pupa, and adult stages. Each female lays up to 280 black, shiny eggs (1 x 0.4 mm), mainly at night, from mid-July to late September. Adults are most abundant in late August and early September. Eggs are laid on the soil surface or at depths of less than 1 cm, and, when newly laid, are extremely susceptible to desiccation. Eggs hatch 11-15 days following oviposition.

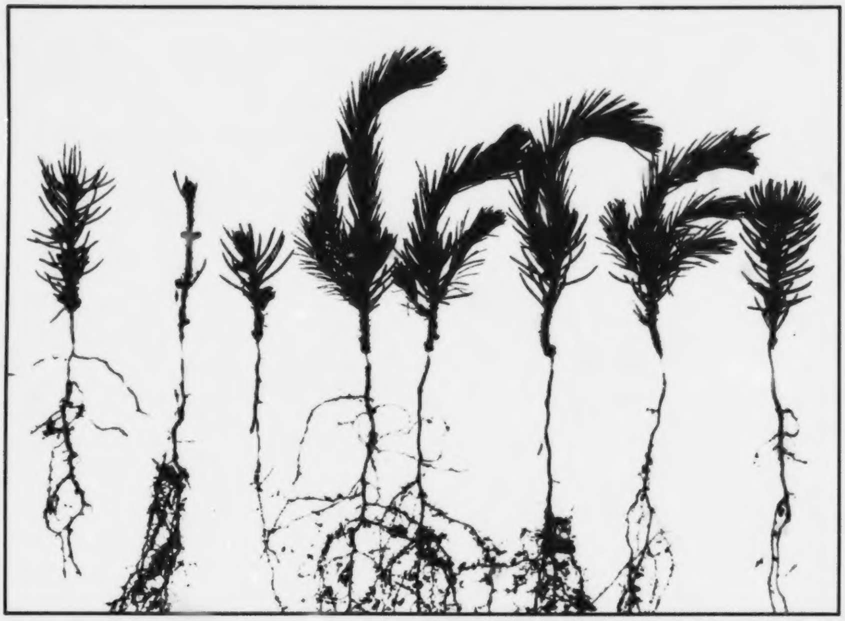


Figure 76. White spruce damaged by larvae (leatherjackets) of the European marsh crane fly.

The gray, legless larvae (3 mm long), called leatherjackets (Figure 78), begin feeding immediately and continue to do so throughout the fall and during warm periods in winter. The larvae are usually in the upper 3 cm of soil.

Larvae grow rapidly in spring and reach their full length of about 4 cm by April or May. About mid-May, they stop feeding heavily and feed lightly until they pupate about mid-July. Pupae are brown, spiny and about 3.3 cm long, and remain underground for about 2 weeks before working their way to the surface, where the empty pupal case is often left protruding from the soil by the emerging adult. Adults emerge after sunset and mate immediately. They resemble giant mosquitoes (Figure 79) and have a grayish brown body, about 2.5 cm long (not including legs), two narrow wings, and very long (17 to 25 mm) brown legs. Adults are weak fliers. Males live about 7 days; females 4-5. Mild winters, cool summers, and rainfall averaging about 600 mm favor the pest.

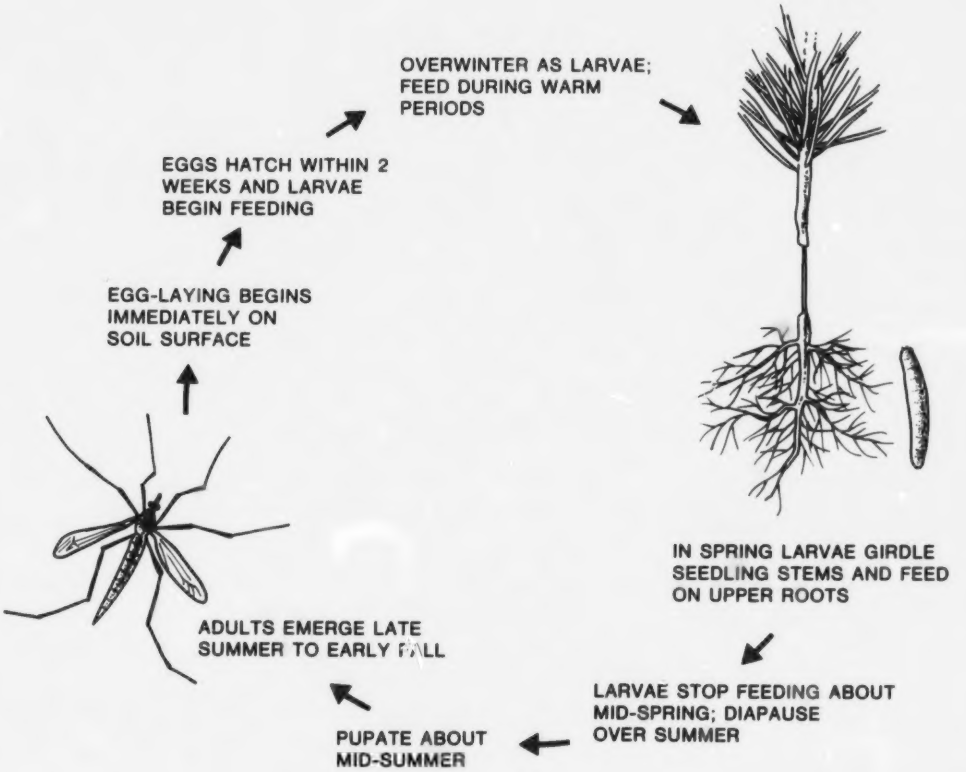

OVERWINTER AS LARVAE; FEED DURING WARM PERIODS
IN SPRING LARVAE GIRDLE SEEDLING STEMS AND FEED ON UPPER ROOTS
LARVAE STOP FEEDING ABOUT MID-SPRING; DIAPAUSE OVER SUMMER
PUPATE ABOUT MID-SUMMER
ADULTS EMERGE LATE SUMMER TO EARLY FALL
EGG-LAYING BEGINS IMMEDIATELY ON SOIL SURFACE
EGGS HATCH WITHIN 2 WEEKS AND LARVAE BEGIN FEEDING

Figure 77. Life history of the European marsh crane fly (one generation per year).

European marsh crane fly

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	2 + 0	Early spring	Yes	No	Yes	No

Management

Seedbeds in the vicinity of areas where damage has occurred during the previous spring or where large numbers of adults have been seen in August or September should be checked for leatherjackets. This is best done in early spring by treating several 30 cm^2 plots in the suspected seedbeds with 1 cup of an insecticide drench (consult an entomologist for a recent recommendation), which will cause the leatherjackets to squirm out of the soil so they can be counted.

Adult crane flies can also originate from lawns, pastures, fields of forage crops, and grassy banks of drainage ditches adjacent to nurseries, especially if any of these contain wet areas. Insecticide sprays against adults are of no value because crane flies do not feed and they mate and lay their eggs shortly after emerging. Since larvae readily accept baits, it may be worthwhile to apply these to seedbeds in March and April, when larvae are foraging above the ground on warm, cloudy days. Larvae can also survive in fallow soil by eating decaying seedling or weed roots. Thus, when these areas are infested they can be disked during the dry part of the summer and fall to kill the larvae, which are very susceptible to desiccation. Crane flies prefer wetter soils; thus, the drainage of areas with habitual outbreaks should be checked and, if necessary, improved.

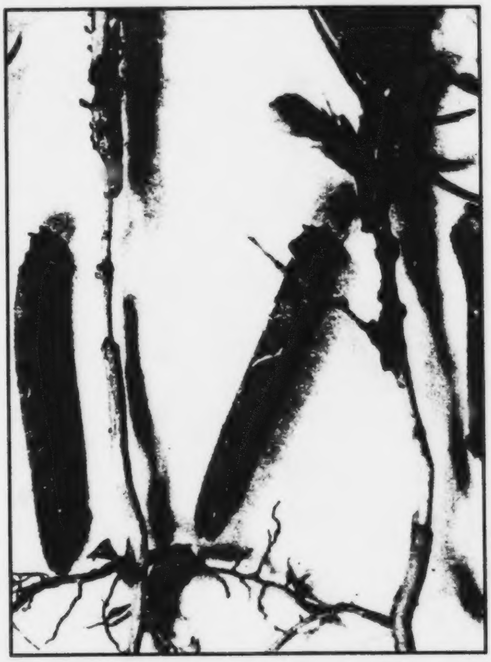


Figure 78. Damaged white spruce, and larvae of the European marsh crane fly.

At nurseries where leatherjackets are a chronic problem, susceptible stock should be drenched with an insecticide in October when young larvae are at their most susceptible stage. Sprays should be irrigated in to the top 5 cm of the soil or growing medium in the evening when leatherjackets come to the surface to browse.

Selected References

Edwards, C.A. and G.W. Heath. 1965. The principles of agricultural entomology. C.C. Thomas, Springfield, Ill.

Wilkinson, A.T.S. and H.R. MacCarthy. 1967. The marsh crane fly, *Tipula paludosa* Mg., a new pest in British Columbia (Diptera: Tipulidae). J. Entomol. Soc. Brit. Col. 64: 29-34.

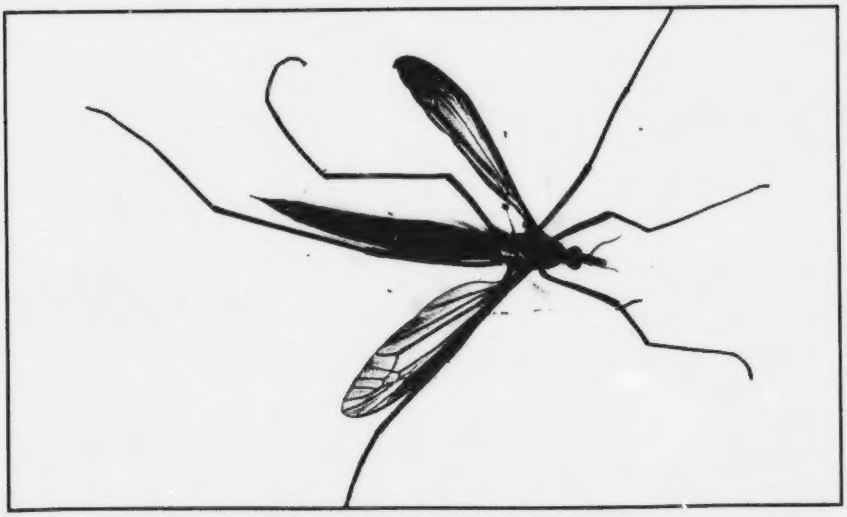


Figure 79. Adult (female) of the European marsh crane fly.

Springtails

These tiny insects (order Collembola) are usually less than 6 mm long and often gray, and have an appendage-like structure on their abdomen which allows them to jump through the air for several centimeters. Their common name, "springtail," originates from this peculiar behavior. Springtails are abundant in most soils throughout the world. They feed on many living and dead plant materials. Springtails occur in all bareroot and container nurseries in the province. Locally, there are several species, few of which have been identified.

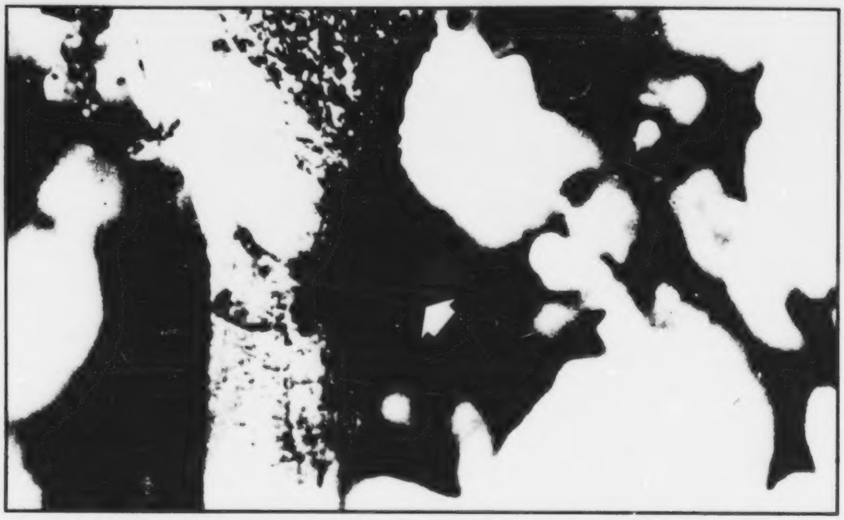


Figure 80. Springtail (at arrow) feeding on germinant (courtesy of V.G. Marshall).

Hosts and damage

In British Columbia, the globular shaped *Bourletiella hortensis* (Figure 80) is the most damaging species in bareroot nurseries, and can build up to alarming numbers. The insect reduces emergence of spruce (Engelmann, Sitka, and white) and western hemlock. They feed on the rising 1+0 seedlings in the spring (Figure 81), attacking the hypocotyl area between the needles and the roots, and producing small lesions that may result in deformation or mortality. These lesions can also serve as entry points for pathogenic fungi. All coniferous species are susceptible hosts during the 3-week period between germinant emergence and seedcoat shed. Springtails are no longer a threat once stems become woody. Several unidentified species of springtails have also been found on container stock, particularly on styroblocks containing algae, moss, or liverworts. Although no damage has been reported on container seedlings, springtails are important pests in other crops using artificial growing media where they may feed on root tips.

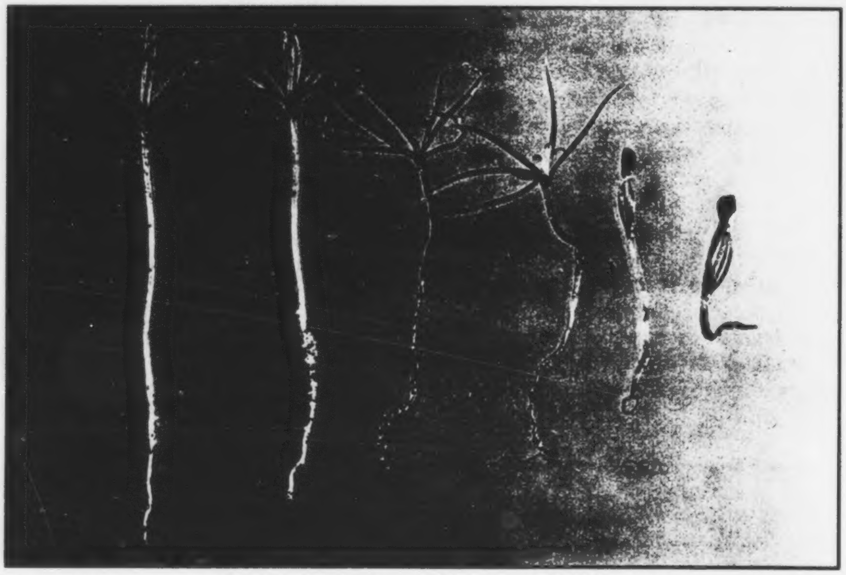


Figure 81. Spruce seedlings affected (four, right-hand-side) and unaffected (two, left-hand-side) by the springtail *Bourletiella hortensis* (courtesy of V.G. Marshall).

Springtails

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All spruce, western hemlock	1 + 0	Spring through early summer	Yes	Yes	Yes	Yes

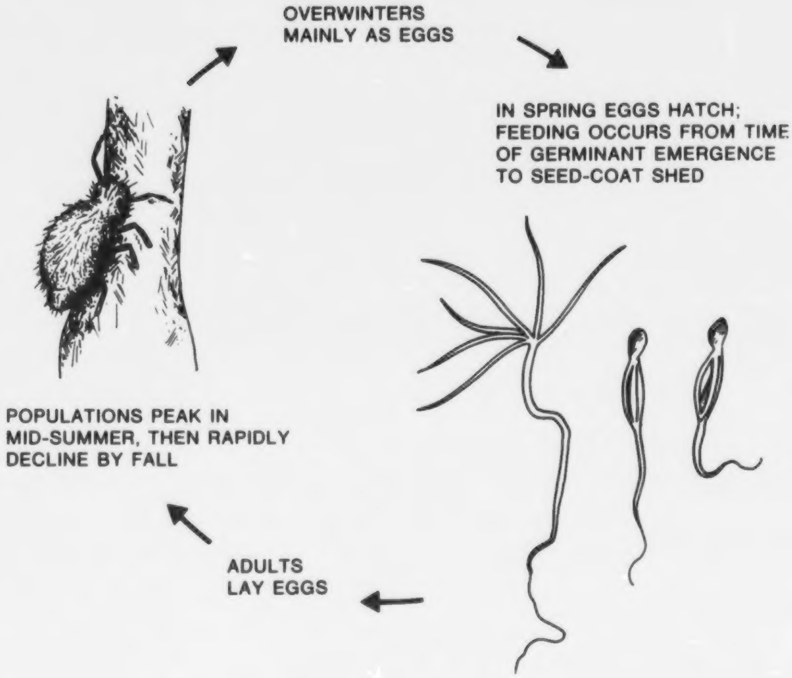

OVERWINTERS MAINLY AS EGGS
IN SPRING EGGS HATCH; FEEDING OCCURS FROM TIME OF GERMINANT EMERGENCE TO SEED-COAT SHED
ADULTS LAY EGGS
POPULATIONS PEAK IN MID-SUMMER, THEN RAPIDLY DECLINE BY FALL

Figure 82. Life history of springtails (one or two generations per year).

Life history (Figure 82)

Under coastal British Columbia conditions, springtails apparently overwinter as eggs and the populations peak in mid-July, then decline to low levels by mid-September. Collembola do not undergo metamorphosis; consequently, except for small size and lack of sexual maturity, juveniles look much like adults, which are about 1.5 mm long and appear to the naked eye as blackish to dark green. The antennae are about half as long as the body and the abdomen is globular.

Management

In bareroot nurseries, routine pre-emergent applications of herbicides usually control springtails. Their populations can be monitored by the waving of a piece of white paper over the seedbed surface. Any insects present will jump when disturbed. If large numbers are visible and damage is present, it may be necessary to apply an insecticide. Cultivation of fallow-infested soils may help destroy eggs.

Selected References

Edwards, C.A. and G.W. Heath. 1965. The principles of agricultural entomology. C.C. Thomas, Springfield, Ill.

Marshall, V.G. 1978. Gut content analysis of the collembolan *Bourletiella hortensis* (Fitch) from a forest nursery. Rev. Ecol. Biol. Sol. 15: 243-250.

Marshall, V.G. and S. Ilnytzky. 1976. Evaluation of chemically controlling the collembolan *Bourletiella hortensis* on germinating Sitka spruce and western hemlock in the nursery. Can. J. For. Res. 6: 467-474.

June beetles (white grubs)

In British Columbia, seedlings in newly established bareroot nurseries have occasionally been damaged by white grubs, which are June beetle larvae. Several June beetles occur in British Columbia. *Polyphylla decemlineata* is probably the most common and destructive in forest nurseries.

Host and damage

Adult *P. decemlineata* feed on coniferous foliage without doing much harm, but larvae feed on – and severely damage – roots of many kinds of plants, including several conifers. Bareroot seedlings can be affected at any age, but especially as 1+0 and 2+1 stock. To date, container-grown seedlings have not been affected. Damage normally occurs in late spring through summer, when white grubs voraciously feed on roots, causing shoots to turn brown and dry out. Frequently, the main stem of seedlings or transplants is cut off slightly below the soil surface (Figure 83), so that affected seedlings can easily be pulled from seedbeds.

White grubs occur around the roots of damaged seedlings or can be found at the time of seedbed preparation, sowing, and planting. Grubs often move from one seedling to another, affecting several adjacent drill or transplant seedlings. Grasses are excellent white grub hosts. Thus, recently established nurseries on former sod areas frequently suffer damage, and distribution coincides with that of the plowed-under sod. Depending upon environmental and other factors affecting the insect's development, white grub damage may peak at 3- or 4-year intervals. Because of climate, insect life history, and previous cropping history factors, damage may be acute, with seedling losses of up to 30% being common in small areas.

Life history (Figure 84)

Depending mainly upon climatic factors, the life cycle requires 3 or 4 years for completion. Grubs and adults overwinter in the soil, and in late June and early July adults emerge on warm evenings, mate, and return to the soil. These flights are repeated daily for 2-3 weeks. Eggs are

3.4 x 2 mm, slightly oval, and creamy-white. They are deposited in the soil and hatch after 2-6 weeks. For the remainder of this growing season, and for the following two, larvae feed on organic matter and roots near the soil surface. Pupation occurs early to mid-summer in the 3rd year of development, in cells about 10 cm below the soil surface.

White grubs have curved, milky-white, thick bodies (0.3-3.1 cm long, depending upon age) with three pairs of prominent legs and darker, chitinized heads and mouths. The hind part of the body is smooth and shiny, the body contents showing through the skin (Figure 85). There are two rows of minute hairs on the underside of the last segment that distinguish white grubs from similar looking larvae.

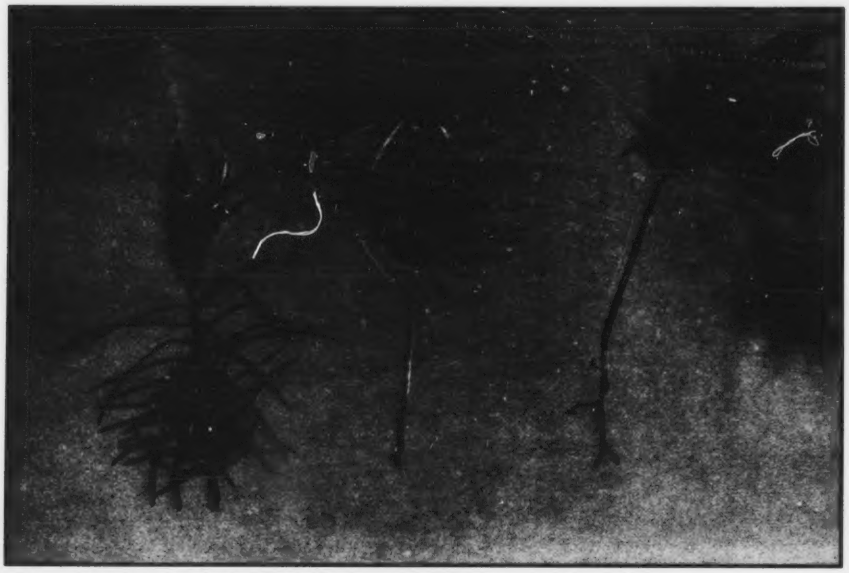


Figure 83. Douglas-fir damaged by June beetle larvae (white grubs).

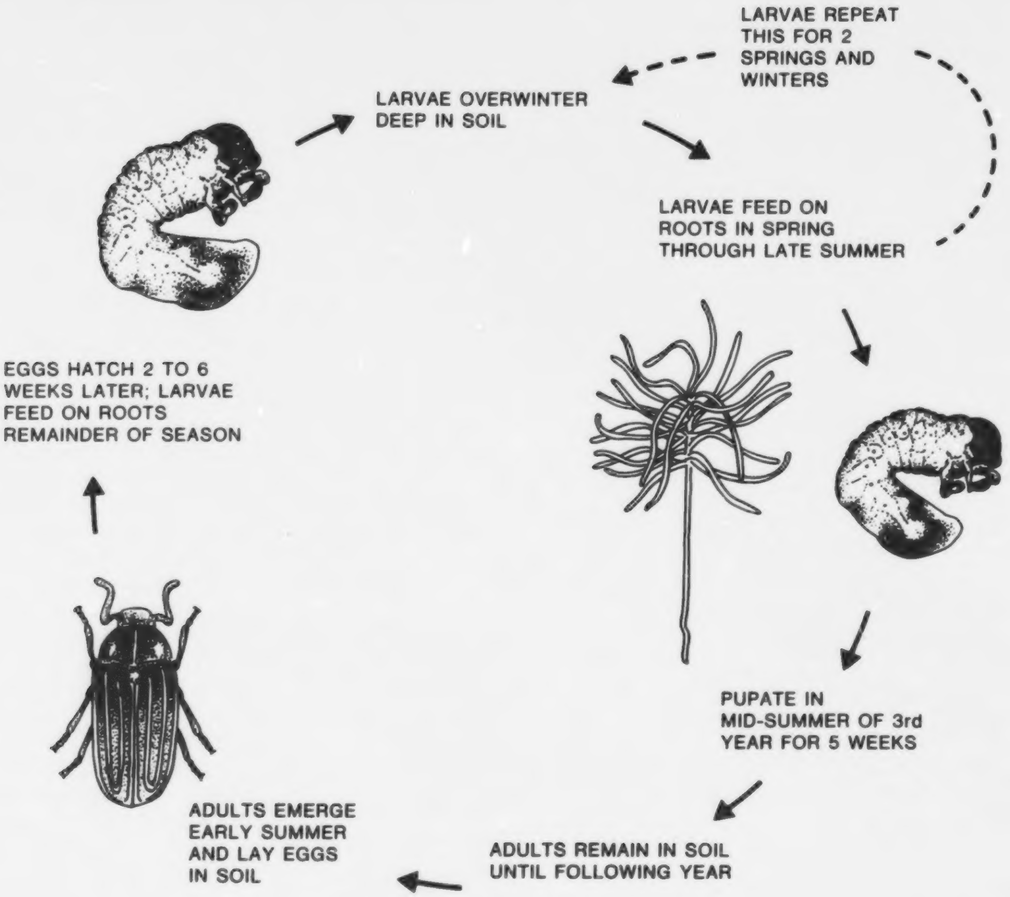

LARVAE REPEAT THIS FOR 2 SPRINGS AND WINTERS
LARVAE OVERWINTER DEEP IN SOIL
LARVAE FEED ON ROOTS IN SPRING THROUGH LATE SUMMER
EGGS HATCH 2 TO 6 WEEKS LATER; LARVAE FEED ON ROOTS REMAINDER OF SEASON
PUPATE IN MID-SUMMER OF 3rd YEAR FOR 5 WEEKS
ADULTS EMERGE EARLY SUMMER AND LAY EGGS IN SOIL
ADULTS REMAIN IN SOIL UNTIL FOLLOWING YEAR

Figure 84. Life history of June beetles (3-year life cycle).

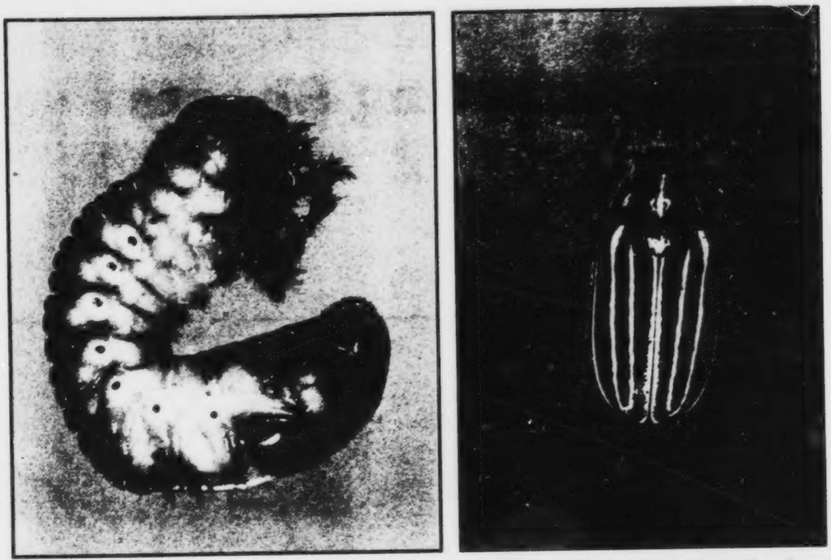


Figure 85. June beetle larva, white grub (left) and adult of the ten-lined June beetle.

June beetles

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	1 + 0 2 + 0 Transplants	Late spring through summer	Yes	Yes	No	No

Management

Nursery managers should familiarize themselves with the local 3- or 4-year peak population cycle, in anticipation of possible grub damage. Light traps can be used to monitor adult population levels. Areas that have been in sod for 2 or more years and are to be converted to forest nursery, and infested fallow soils in long-established nurseries, should be shallow-plowed and frequently disked in early summer. Sometimes, pre-plant soil fumigation may be needed to rid an area of grubs. Insecticide drenches are sometimes applied to infested seedbeds, but they are expensive and may be ineffective because of the difficulty of distributing the material throughout the soil. Also, the short-lived efficacy of many of today's insecticides necessitates repeated applications.

Selected References

Banham, F.L. and J.C. Arrand. 1970. Recognition and life history of the major insect and applied pests of vegetables in British Columbia. B.C. Dep. Agric., Bull. 70-9, Victoria, B.C.

Downes, W. and H. Andison. 1940. Notes on the life history of the June beetle *Polyphylla perversa* Casey. Proc. Entomol. Soc. Brit. Col. 37: 5-8.

Insects and Mites Affecting Shoots

Cutworms

Larvae of several moths (order Lepidoptera) occur incidentally in forest nurseries and, although often causing cutworm-like damage, they are not true cutworms. This designation applies only to larvae of moths in the family Noctuidae, of which the variegated cutworm *Peridroma saucia* is probably the most common and damaging in local forest nurseries.

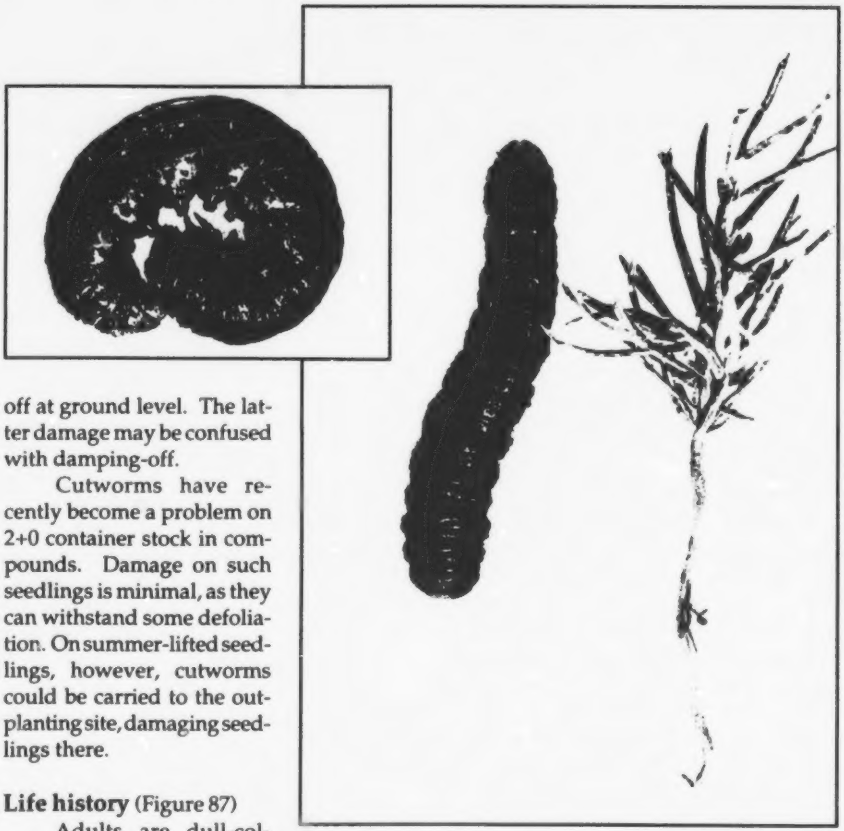


Figure 86. Typical cutworm and cutworm-damaged seedling (cut off at groundline).

Hosts and damage

Some cutworm damage likely occurs in all nurseries every year. All coniferous species in both bareroot and container nurseries throughout the province may be attacked, but severity of infestation varies greatly. Damage is generally confined to young, succulent seedlings before their stems become woody. A single larva can destroy many seedlings each night, thus only a few cutworms per m^2 can destroy thousands of seedlings in a few weeks. Cutworms feed on foliage (Figure 86) and often cut through the stems just above ground, leaving a short stump. The following are indicators of cutworms: (i) stems on which the needles have been consumed, (ii) sunken or depressed areas on the stems that look like fungus-caused lesions (these are old feeding sites), (iii) stems cut off below the soil so it appears that the seedling did not germinate, and (iv) stems cut off at ground level. The latter damage may be confused with damping-off.

Cutworms have recently become a problem on 2+0 container stock in compounds. Damage on such seedlings is minimal, as they can withstand some defoliation. On summer-lifted seedlings, however, cutworms could be carried to the outplanting site, damaging seedlings there.

Life history (Figure 87)

Adults are dull-colored, heavy-bodied, night-flying moths about 18 mm long. Their wings are folded tent-like when resting. Larvae are large, soft, fat, wormlike, dull-colored caterpillars up to 4 cm long, with hairless bodies and shiny heads. They characteristically assume a curled position (Figure 86), especially if disturbed. Variegated cutworm larvae (Figure 88) have a single line of four or more yellowish orange dots on the upper body surface. Cutworms pass through egg, larva, pupa, and adult stages and, depending on the species, can have one to three or more generations per year. The number of variegated cutworm generations per year varies according to climate. Locally, one or two normally occur, but this may increase in certain localities in warmer years. The

Cutworms

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	1 + 0 2 + 0 Transplants	Throughout growing season	Yes	Yes	Yes	Yes

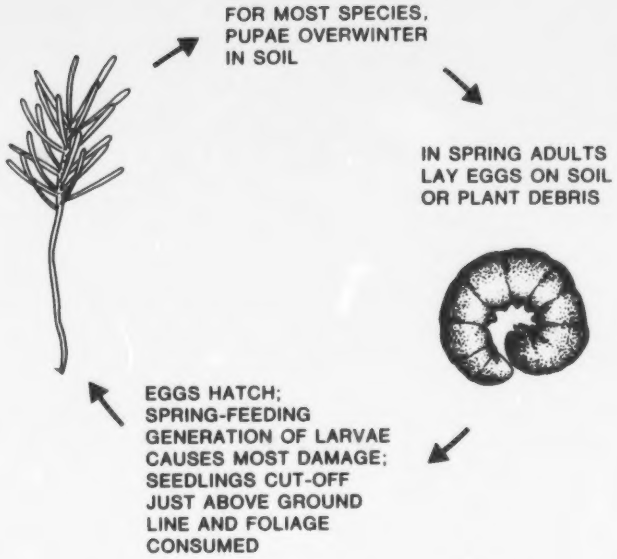

FOR MOST SPECIES, PUPAE OVERWINTER IN SOIL
IN SPRING ADULTS LAY EGGS ON SOIL OR PLANT DEBRIS
EGGS HATCH; SPRING-FEEDING GENERATION OF LARVAE CAUSES MOST DAMAGE; SEEDLINGS CUT-OFF JUST ABOVE GROUND LINE AND FOLIAGE CONSUMED

Figure 87. Life history of cutworms (up to three or more generations per year).

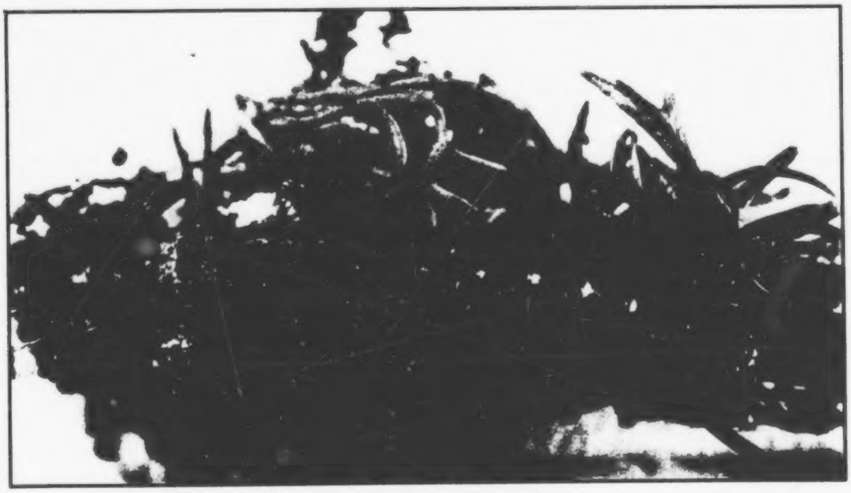


Figure 88. Variegated cutworm *Peridroma saucia.*

spring generation is the most damaging, because its occurrence coincides with seedling germination. The larvae, which feed at night and hide during the day, are often difficult to detect. They may be easier to locate in container stock because they hide in the container cavity, disturbing the covering surface, or in moist areas between styroblocks. Depending on the species, cutworms can overwinter in most life stages.

Management

Fallow, bareroot fields should be kept weed-free to reduce egg-laying females, which are attracted to certain weeds. However, once cutworms are present, killing weeds may drive larvae from preferred weeds to seedlings. The use of light traps in greenhouses has effectively reduced populations of adult moths. Greenhouses can be insect-proofed to exclude moths. In container nurseries, small outbreaks can be controlled by removing and destroying the cutworms from the growing medium. In both bareroot and container nurseries, poison baits with natural attractants (such as apple pomace or bran) may be used to kill larvae. Where outbreaks are large, insecticides are often used; but where damage is confined, only those areas where seedlings have been damaged should be sprayed. Sprays are most effective against young larvae. They should be applied under warm moist conditions late in the day or in the evening when cutworms are most active.

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Aphids

In general, aphids (order Homoptera) are small, gregarious insects with soft, pear-shaped, green, yellow, black or colorless bodies. Their long, slender legs allow for slow movement. Most species possess "cornicles" - a pair of tube like, truncate, or porelike structures on the dorsal, posterior section of the body. Adults may be wingless or have four transparent, delicate wings.

The most commonly occurring aphids locally are several species of giant conifer aphids of the genus *Cinara*, and the Cooley spruce gall aphid *Adelges cooleyi*. Other aphids that have been pests are the green spruce aphid, *Elatobium abietinum*; the primitive woolly aphid, *Mindarus obliquus*; and two conifer root aphids, *Pachypappa tremulae* and *Prociphilus xyloster*. The balsam woolly aphid, *Adelges piceae* (also known as the balsam woolly adelgid), although a concern because of quarantine regulations, has not been reported at any local nurseries.

Hosts and damage

Each tree species grown in local nurseries is a host for at least one species of giant conifer aphid. Great numbers of these large (3-5 mm long), dark-colored, long-legged aphids (Figure 89) feed gregariously on seedling stems, where they may cause stunting and chlorosis. Their 1 mm long, shiny black, oval-shaped eggs are usually laid individually on needles at the end of summer. Growers should watch for eggs when lifting seedlings, because they will accompany seedlings to planting sites. Adults characteristically produce copious amounts of honeydew on which sooty moulds grow. As well, honeydew attracts ants and wasps, which are good indicators of aphid infestation.

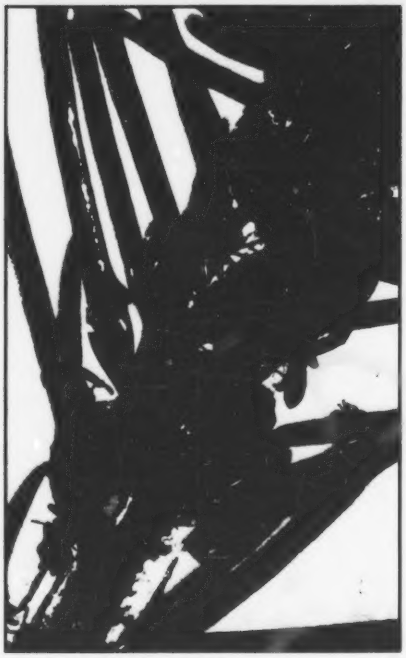

Figure 89. Giant conifer aphids (nymphs and adults) on spruce seedling terminal.

The coniferous root aphid, *Pachypappa tremulae*, previously called *Rhizomaria piceae*, has been a pest at several British Columbia nurseries, particularly near Prince George. Infestations (Figure 90) are most common on container seedlings. Bareroot stock is rarely affected. This aphid's major hosts are container-grown spruce, potted spruce grafting stock, and sometimes pine, larch, and Douglas-fir. To date, infestations on otherwise healthy seedlings have caused no damage; this may not be true for stressed seedlings. Little is known about this aphid's life history, damage, or distribution. The aphids, which are usually most abundant on the exterior roots in the upper portion of the container cavity may go unnoticed until the seedlings are lifted. They secrete white waxy strands that might be mistaken for mycorrhizae. Part of the aphid's life cycle occurs on trembling aspen, *Populus tremuloides* leaves, which may explain the predominance of infestations at nurseries in the north central Interior.

The woolly stage of the Cooley spruce gall aphid can be serious on Douglas-fir and spruce (white, Engelmann, and Sitka) seedlings. The aphids, approximately 1 mm long, are covered in tufts of a white cottony woollike substance and can be found on the lower surface of needles (Figure 91) and shoots year-round. Their feeding (Figure 92) causes mottled, twisted needles, and severe infestations cause stunting and defoliation. Another stage of the aphid can occasionally cause galls on transplant or grafted spruce stock that is at least 3 years old and thus large enough to sustain the galls.

The primitive woolly aphid attacks only spruce seedlings and has been a problem at several British Columbia nurseries. The aphids occur in small colonies at the seedling tip, appearing as white woolly masses. These aphids can cause terminal mortality and deformation. There is little information on this aphid's life cycle or host range.

The balsam woolly aphid has become established in British Columbia and can seriously damage all true firs (Figure 93). It occurs throughout the Lower Mainland and in the southern half of Vancouver Island. To date, it has only been reported in forest stands, never in forest nurseries. Such an infestation is a potential threat to forested areas if infested seedlings are outplanted to reforestation sites. Therefore, all nurseries in the province growing *Abies* must obtain a permit annually from the Ministry of Agriculture and Fisheries to satisfy quarantine regulations.

The green spruce aphid (Figure 94) is a serious pest of spruce species along coastal British Columbia - particularly of Sitka spruce - and may occur on pine and Douglas-fir. Adults are green, 1 mm long with long cornicles. Preferring older needles, they are usually found on the lower shaded needles rather than on leader or growing tips. Initial damage results in mottled needles, followed by chlorosis and needle drop. Severe infestations can lead to complete defoliation and seedling death. They overwinter as adults on foliage and, under mild winter conditions, continue to reproduce and feed. Nursery workers must

Aphids

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Many species, depends upon aphid species	1 + 0 2 + 0	Depends upon aphid species Transplants	Yes	Yes	Yes	Yes

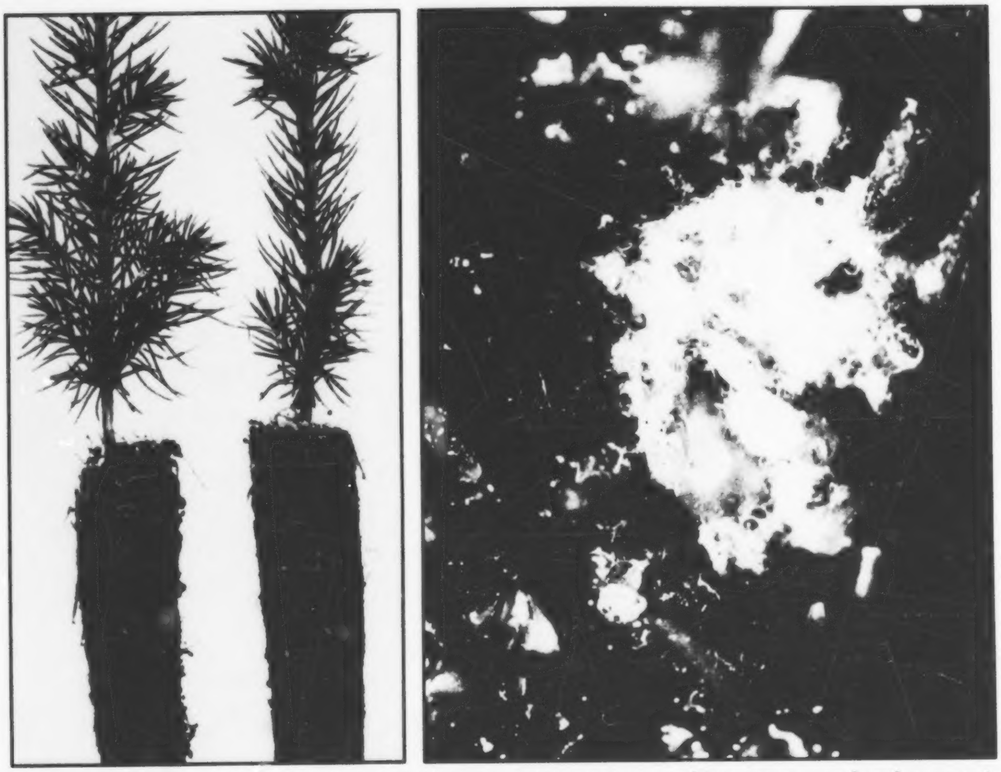

Figure 90. White wool (left) of root aphid on container-grown white spruce, and enlargement (right) showing the aphids.

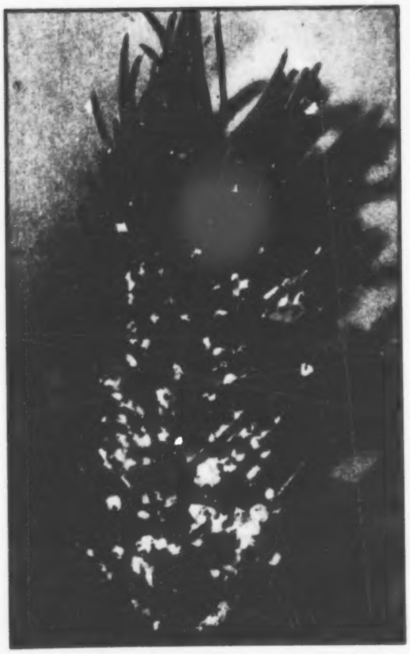

Figure 91. Symptoms and white, cottony wool of Cooley spruce gall aphid on spruce.

therefore, be aware of green spruce aphid populations throughout the year.

Life history[4]

The life history of aphids, including the ones discussed here, is complex. In general, most aphids pass through several generations per year. Populations fluctuate widely and quickly. Some juveniles hatch from eggs, others may be born alive. Overall, except for size, adults and juveniles are similar in appearance. Parthenogenesis is common; however, the last seasonal generation is usually sexual. Overwintering is usually as eggs. Some aphids complete their life cycle on two kinds of plants. Even this relationship may be optional. For example, the Cooley spruce gall aphid normally requires Douglas-fir and spruce to complete its life cycle, but certain wingless generations may live only on spruce or Douglas-fir.

Management

Aphid damage usually does not occur until populations are large; however, population build-up can be fast and erratic. Predicting aphid outbreaks is difficult in nurseries, but the presence of wasps or ants is a good indicator of aphids. Wasps feed on both honeydew and aphids, and can effectively control small populations. However, it is virtually impossible to exclude aphids from the nursery, as they are frequently blown in by the wind. All these factors justify waiting until populations have been detected before controls such as insecticidal soaps or insecticides are applied. The probability and intensity of *A. cooleyi* outbreaks may be decreased by excluding spruce in windbreaks or the nursery periphery adjacent to Douglas-fir seedbeds.

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[4] Because of the variation in the life history of the aphids described here, a diagram is not included.

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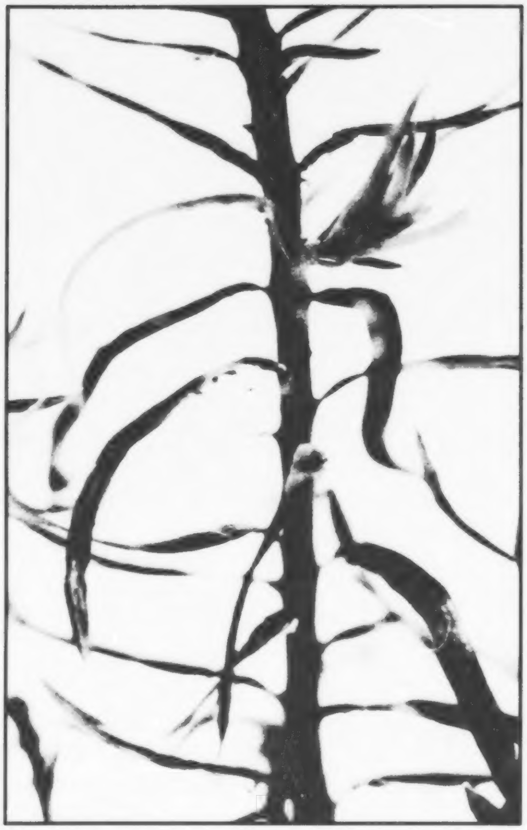

Figure 92. Twisting and distortion of needles of Douglas-fir seedling caused by Cooley spruce gall aphid.

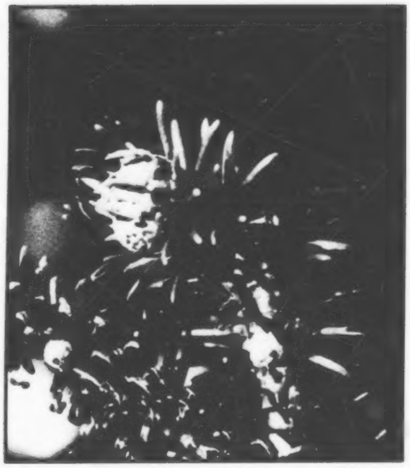

Figure 93. True fir showing balsam woolly aphid damage. Note stunted needles and galled buds.

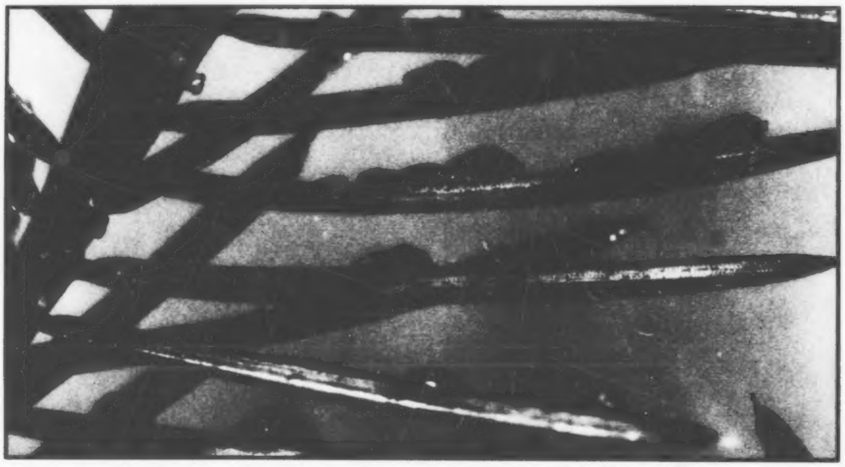

Figure 94. Green spruce aphids. Note mottled spruce needles (courtesy of Forest Insect and Disease Survey, P.F.C., Victoria, B.C.).

Lygus bug

Lygus lineolaris was first identified in British Columbia as a serious pest in bareroot and container nurseries in 1983. Damage can now be found at many nurseries and on most conifer species across the province. Feeding by the adults and nymphs initially causes distortion of seedling terminal shoots, which later become multiple-leadered. This insect is an important pest of many agricultural crops and has a wide range of native hosts.

Hosts and damage

To date, the major host of the *Lygus* bug in British Columbia appears to be 1+0 bareroot (Figure 95) and container pine, although significant damage has also occurred on larch, Douglas-fir, and both 1+0 and 2+0 spruce. *Lygus* bugs feed on rapidly growing tissue such as growing tips, buds, and flowers. Both adults and nymphs feed by sucking plant juices, while simultaneously introducing a toxic saliva into the plant. General symptoms begin to appear within a few weeks and an elongate scar often shows down one side of the stem.

Feeding usually results in the loss of apical dominance and the development of weak multiple leaders. In pine, a distinctive terminal distortion results. Needles (Figure 96) are thicker and shorter, and twisted with the entire seedling tip curled over. Mature foliage may develop. The bud, if present, grows at an angle. In spruce, attack results in a checking or shepherd's crook forming at the stem tip, which subsequently often develops into two leaders. Damage in both bareroot and container nurseries has an edge distribution. In pine, damage often occurs in patches of two to five seedlings; in spruce it appears as a single attack.

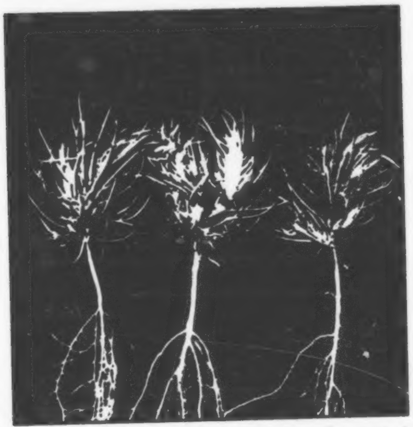

Figure 95. *Lygus* bug damage on bareroot pine.

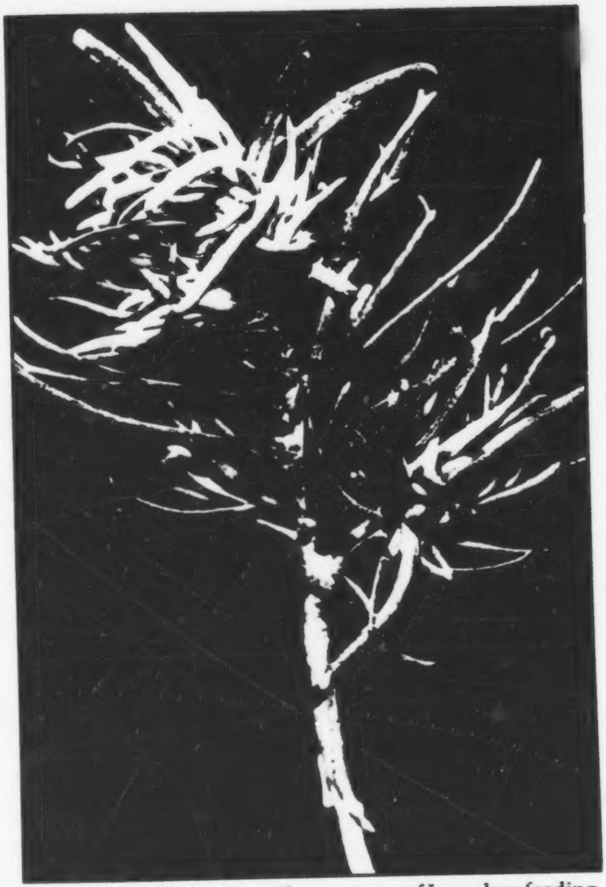

Figure 96. Bareroot pine with symptoms of *Lygus* bug feeding. Note stunted needles and twisted terminal.

Life History

(Figure 97)

Lygus bug adults (Figure 98), 7 mm long and half as wide, are broad, flattened, and oval-shaped with a small projecting head. They range in color from yellowish-green to reddish-brown and are covered with small, irregular splotches of white, yellow, reddish-brown, and black. Adults overwinter in the crowns of plants and in debris, and remain active under mild conditions. They become active very early in the spring, feeding on newly developing buds and shoots. Soon after, emerging adults mate and insert single eggs full length into many different plants. Eggs are elongate, slightly curved, and the outer end of each is cut off squarely, with a lid that is usually flush with the stem. Nymphs, which emerge in about 10 days, are 1 mm long, yellowish-green, and similar in appearance to aphids, although they move around more rapidly. Nymphs grow quickly, molting five times. Older nymphs are marked with rounded black dots: four on the thorax and one on the base of the abdomen.

The life cycle is completed in 3-4 weeks. There are two or three generations per year in British Columbia. By late summer, *Lygus* bugs occur everywhere in profusion, but because of their protective coloration and hiding habits they are rarely noticed.

Management

It may be necessary to control these insects, which are very active throughout

***Lygus* bug**

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species, larch, Douglas-fir, spruce, especially pines	1 + 0 2 + 0	Spring through summer	Yes	Yes	Yes	Yes

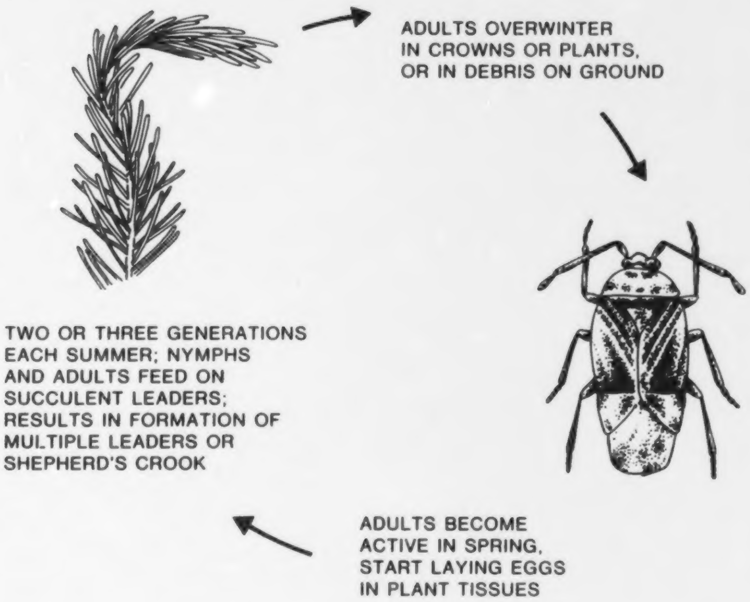
ADULTS OVERWINTER
IN CROWNS OR PLANTS,
OR IN DEBRIS ON GROUND
TWO OR THREE GENERATIONS
EACH SUMMER; NYMPHS
AND ADULTS FEED ON
SUCCULENT LEADERS;
RESULTS IN FORMATION OF
MULTIPLE LEADERS OR
SHEPHERD'S CROOK
ADULTS BECOME
ACTIVE IN SPRING,
START LAYING EGGS
IN PLANT TISSUES

Figure 97. Life history of *Lygus* bug (two or three generations per year).

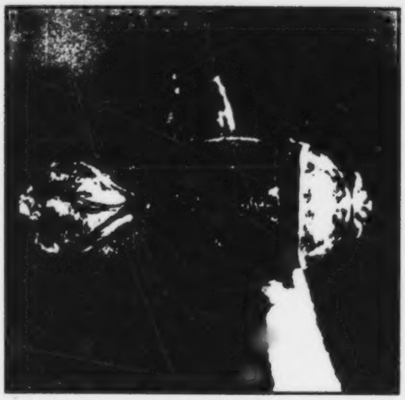

Figure 98. Adult *Lygus* bug.

the growing season and readily invade nurseries from mid-May to late September. Stock is most susceptible during the 1st year of growth, from the time true or secondary needles have developed until budset. A preventive program of insecticidal foliar sprays applied during the 1st week of June, July, and August has reduced seedling damage in areas where the insect has been a chronic pest. Because the *Lygus* bug has a wide range of native hosts, keeping the nursery and surrounding area free of weeds and other possible alternative hosts will help reduce migrating populations.

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Mites

Many species of spider mites (order Acariformes), distributed throughout the North Temperate zone, attack a wide variety of plants. The spruce spider mite, *Oligonychus ununguis*, is the mite pest of greatest concern in British Columbia container and bareroot nurseries. However, recent infestations of *Trisetacus* species at several bareroot nurseries (Figure 99) indicate that this mite is also a problem. Other mites are often observed on seedlings and are usually harmless. Recently, large numbers of the genus *Linopodes* have been found at several nurseries. They have long, slender legs, the two front ones being twice as long as the others, enabling them to jump and walk backwards quickly. They are not pests of plants.

Figure 99. *Trisetacus* mite damage on bareroot pine.

Hosts and damage

The spruce spider mite feeds on the foliage of several conifers, including cedars, Douglas-fir, true firs, hemlocks, larches, pines, and spruces. It inserts its stylet-like mouthparts into needles and tender twigs and sucks out the cell contents, causing a mottled, bleached discoloration and subsequent drying of the needles (Figure 100). Severely affected foliage turns dingy-yellow to dull, rusty-brown and the needles drop off. Immature and adult mites spin a fine, silk webbing around and among the needles of infested twigs. The abundance of this webbing (Figure 101), especially noticeable when branches and twigs are viewed from the underside, increases as the season progresses. The webbing usually contains eggs and cast mite skins, and protects the mites from dislodgement and from some of their natural enemies. The mites can be seen directly on foliage with a hand lens or by the tapping of an infested twig over a white sheet of paper.

To date, the spruce spider mite has been a sporadic pest on bareroot and container stock at coastal and interior nurseries. Certain seedlots are affected more than others. However, the potential for damage is probably greatest in southern interior nurseries because hot, dry conditions favor the pest. Low host vigor, host crowding, and absence of natural enemies also enhance spider mite outbreaks. Consequently, damage is most likely to occur in late summer to early fall when seedlings are often being stressed for water and nutrients to induce dormancy.

Full knowledge of host range, distribution, and damage of the *Trisetacus* mite has not yet been attained. It has been identified on 2+0 production stock, nursery outplanting stock, and grafting stock, and in an interior reforestation site. The natural range is coastal, but if introduced into the Interior it may become established. Its hosts include lodgepole, shore, and Scots pine. Interior provenances of trees are more seriously affected than are coastal provenances. These mites live in colonies in needle sheaths where they damage epidermal tissue, destroying the entire needle base which becomes brown, necrotic, and sometimes calloused. Needles (Figure 102) then become chlorotic, stunted, and often twisted or crinkled with needle growth reduced up to 70%. Infested needles may drop. Most damage occurs in the spring. Locally the problem is called "kinky disease."

Life history (Figure 103)

There are five stages in the life cycle of the spruce spider mite: egg, larva, two nymphal stages, and adult. Eggs are pale yellow when laid and gradually become reddish brown. During a warm, dry season, hatching begins in late spring to early summer. Development of larvae and nymphs requires 3-6 days, respectively. Newly hatched larvae are pink, becoming needle-green after feeding. They have three pairs of legs. Nymphs are mottled, needle-green to dark-green. Like the adults, they have four pairs of legs. Nymphs become adults by early summer and may live up to 30 days. Adults are very small (0.4-0.6 mm long), dark-green to dark-brown, and move about fairly rapidly. Each female lays as many as 50 eggs. There may be up to seven succeeding generations of mites per season - that is, about one new generation each 15 days. Larvae, nymphs and adults

Mites

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Several species	1 + 0 2 + 0 Transplants	Late summer to early fall	Yes	Yes	Yes	Yes

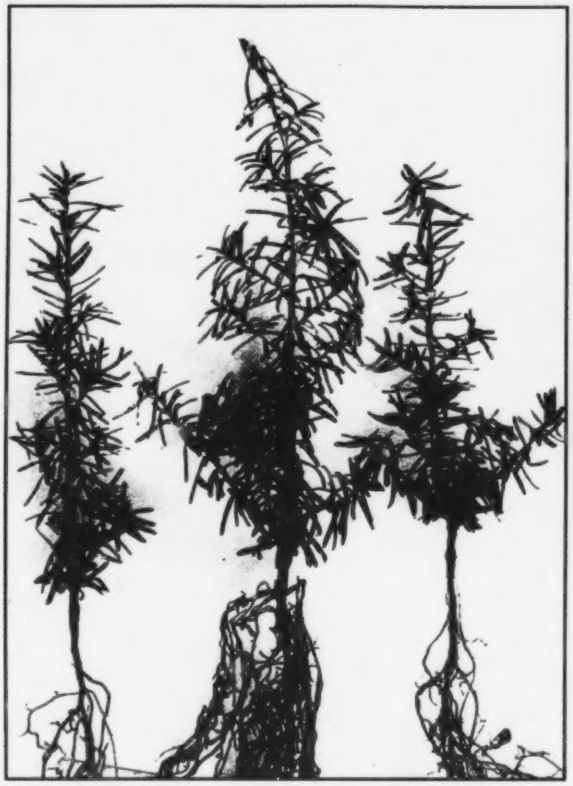


Figure 100. Mountain hemock damaged by the spruce spider mite.

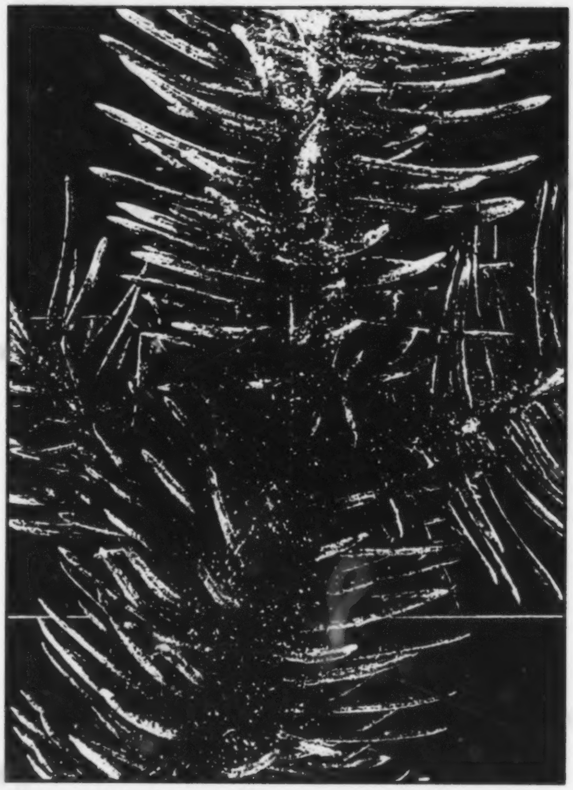


Figure 101. Webbing of the spruce spider mite on affected foliage (courtesy of G.B. Neill).

all feed, the spring generation on old foliage and subsequent generations on current foliage. Overwintering eggs are laid in autumn under loose bud scales and bases of needles. Outbreaks can originate from overwintering eggs or be windblown into nurseries.

Trisetacus mites are very small, less then 0.3 mm long, and very slow moving. They are light yellowish-white, elongate, and wormlike with all their legs at the anterior end. Colonies found in needle sheaths, where they overwinter as well, can have up to 200 mites, but damage can be caused by 10-20. The population overwinters as both adults and eggs within the needle sheaths. During the time of candle elongation in the spring, the mites move to the new growth and lay several overlapping generations of eggs. It is at this time that they cause considerable damage to the new needles producing the symptoms of kinky disease. During the summer, as necrotic tissue begins to develop at the needle base, the mites often disappear; presumably they move on to healthy needles.

Management

Mite infestations can build up rapidly and management is often necessary. Spider mite populations on trees around the nursery should be monitored, particularly during long, warm-dry summer periods, because these mites can be windblown into the nursery. Where practical (e.g., in small outbreaks), affected seedlings can be washed daily with a strong stream of water to wash away the mites and break up the webbing protecting them and their eggs. Sometimes, miticide use may be necessary, especially where water washings might be undesirable, such as in large outbreaks or where the water might break dormancy of stock destined for storage or shipping. When using a miticide, current recommendations should be checked; insecticides are usually ineffective against mites. Miticide applications must be made frequently since eggs are resistant, and several different life stages are usually present simultaneously. Outbreaks should be managed late in the season before stock is infested with overwintering eggs and sent to reforestation sites.

Specific controls for *Trisetacus* mites have yet to be established, but as already mentioned, stock destined for reforestation sites should be free of mites. Symptomatic seedlings can be examined with a powerful hand lens by gently removing the needle sheath separating the two needles, and examining their inner surface for mites. The best time to control this pest is from mid-spring to early summer during the period after candle elongation, but prior to needle elongation. At this time the mites move out of last year's needle sheaths and migrate up the shoots into the elongating needles of the new growth. Adding oil to the spray mix helps miticides penetrate through or around the sheath to the infested area.

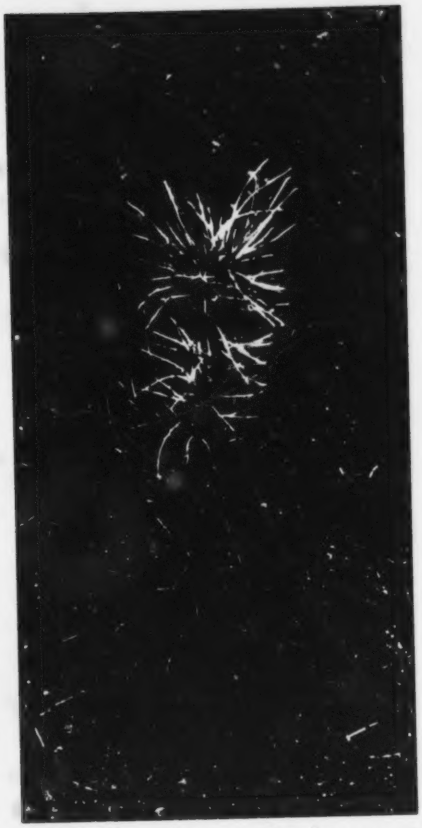
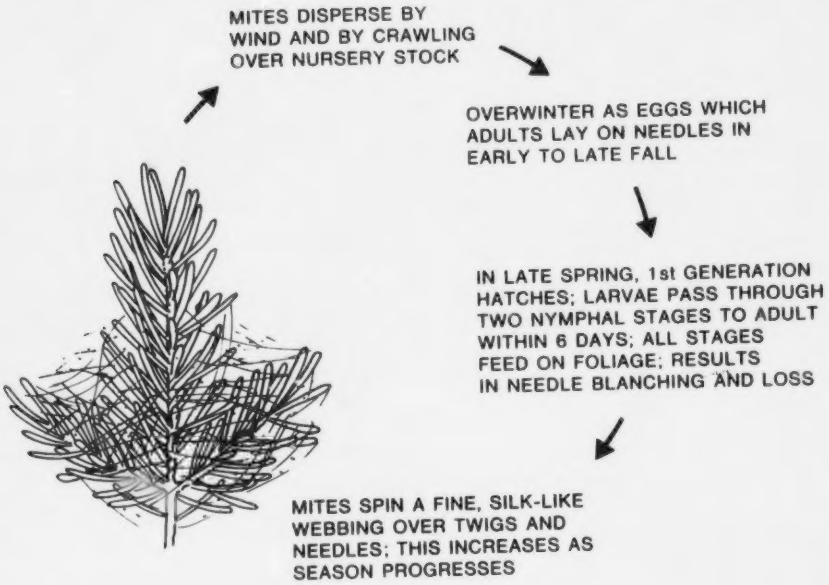


Figure 102. *Trisetacus* mite damage on lodgepole pine. Note stunted, chlorotic needles.



MITES DISPERSE BY WIND AND BY CRAWLING OVER NURSERY STOCK

OVERWINTER AS EGGS WHICH ADULTS LAY ON NEEDLES IN EARLY TO LATE FALL

IN LATE SPRING, 1st GENERATION HATCHES; LARVAE PASS THROUGH TWO NYMPHAL STAGES TO ADULT WITHIN 6 DAYS; ALL STAGES FEED ON FOLIAGE; RESULTS IN NEEDLE BLANCHING AND LOSS

MITES SPIN A FINE, SILK-LIKE WEBBING OVER TWIGS AND NEEDLES; THIS INCREASES AS SEASON PROGRESSES

Figure 103. Life history of spruce spider mite (several generations per year).

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Rusty tussock moth

To date, the rusty tussock moth, *Orgyia antiqua*, although collected from several nurseries throughout the province, has been chronic at only one Lower Mainland nursery.

Hosts and damage

Larvae (Figure 104) attack all conifer seedling species. Although usually a pest of container stock (Figure 105), bareroot seedlings have also been damaged. These gregarious caterpillars completely denude a seedling before moving on to the next, and can occur in patches covering 5-100 styroblocks.

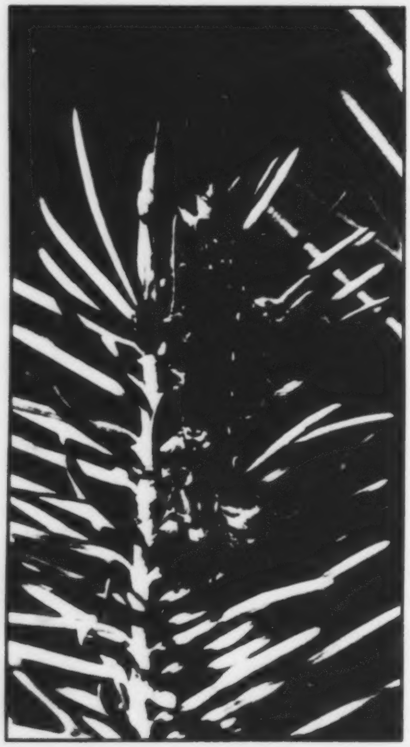

Figure 104. Larva (caterpillar) of the rusty tussock moth.

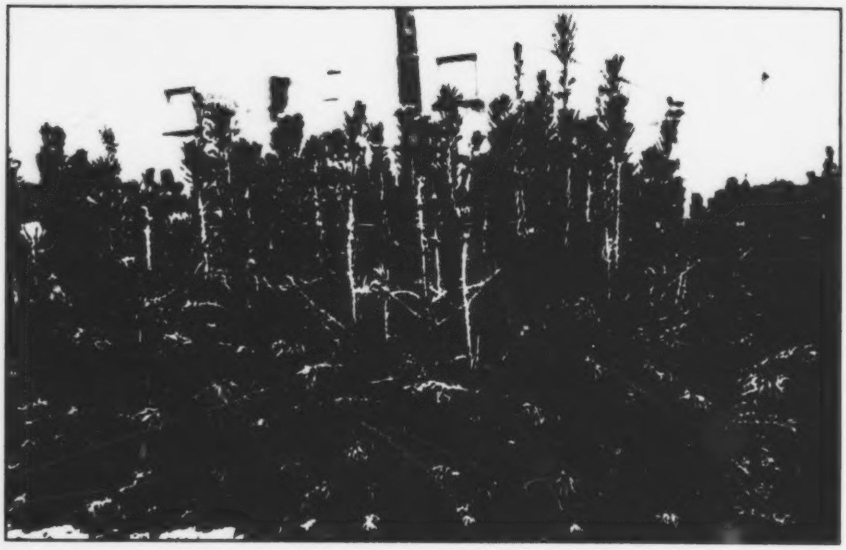

Figure 105. Container-grown spruce with rusty tussock moth feeding damage on needles.

Life history (Figure 106)

The adult male (Figure 107) is rusty-brown with a white dot and light brown band on each forewing. The female is flightless, sedentary, with light tan hairs covering the body. The population overwinters as white egg masses which can be cemented to the sides and bottoms of styroblocks (Figure 108). They will adhere to the blocks after seedlings have been lifted and blocks washed and stored. Because the eggs are white, they often go unnoticed. Larvae emerge from these egg masses (often on styroblocks) around May, and actively feed on newly emerged seedlings. They are hairy, up to 28 mm long, have two black hair "pencils" projecting forward and one to the rear, four golden brushes of hair on the back, accompanied by eight warty protuberances with yellow and black hairs on each segment. A second generation can appear from mid-July to September.

Management

The large, brightly colored larvae are readily seen and, in small infestations, can be hand-picked and killed. The hairs on the caterpillar's body can cause an itchy welt-like rash (tussockosis) in some people. Large infestations can be controlled by insecticidal sprays.

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Rusty tussock moth

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	1 + 0	Spring through early summer	Yes	No	Yes	No

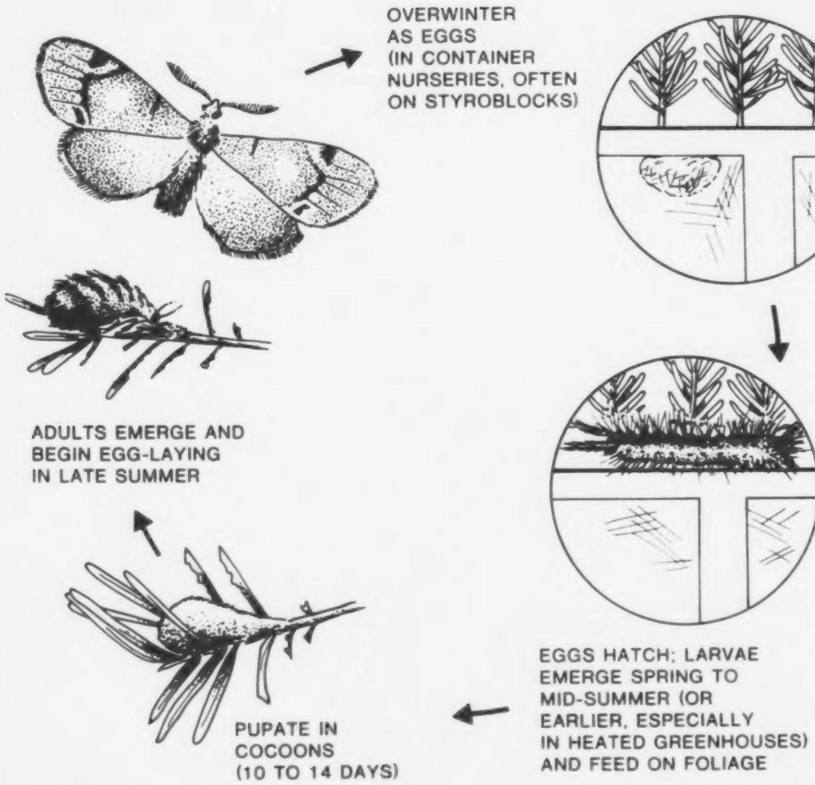
OVERWINTER AS EGGS (IN CONTAINER NURSERIES, OFTEN ON STYROBLOCKS)
EGGS HATCH; LARVAE EMERGE SPRING TO MID-SUMMER (OR EARLIER, ESPECIALLY IN HEATED GREENHOUSES) AND FEED ON FOLIAGE
PUPATE IN COCOONS (10 TO 14 DAYS)
ADULTS EMERGE AND BEGIN EGG-LAYING IN LATE SUMMER

Figure 106. Life history of rusty tussock moth (one or two generations per year).

Figure 107. Male rusty tussock moth.

FISHER SCIENTIFIC

Figure 108. Egg mass of the rusty tussock moth on a styroblock.

Western spruce budworm

The western spruce budworm, *Choristoneura occidentalis,* is a very destructive forest defoliator. Nurseries in or near infested areas can be severely infested by larvae that have overwintered on mature trees. Another budworm, *Choristoneura rosaceana,* has also been an incidental problem in nurseries in British Columbia. Larvae found in early spring, web the top needles of seedlings together.

Hosts and damage

Western spruce budworm affects container and bareroot Douglas-fir (Figure 109) and spruce seedlings. In spring, larvae bore into needles until buds begin to swell, and then they mine expanding buds. Later, they spin loose webs around new foliage and feed within the webbing, often chewing needles off at their bases. They will feed on old foliage once new growth has been destroyed. They are voracious feeders, causing severe defoliation.

Life history (Figure 110)

Adult moths (Figure 111) are mottled orange brown and have a wingspan up to 28 mm. Eggs are light green and laid in shinglelike masses on the underside of needles in mid-July. The resulting larvae overwinter in small silken cocoons which are hard to locate. The following spring, larvae up to 32 mm long (Figure 112), with brownish head and a body having promi-

Figure 109. Bareroot Douglas-fir with western spruce budworm feeding damage.

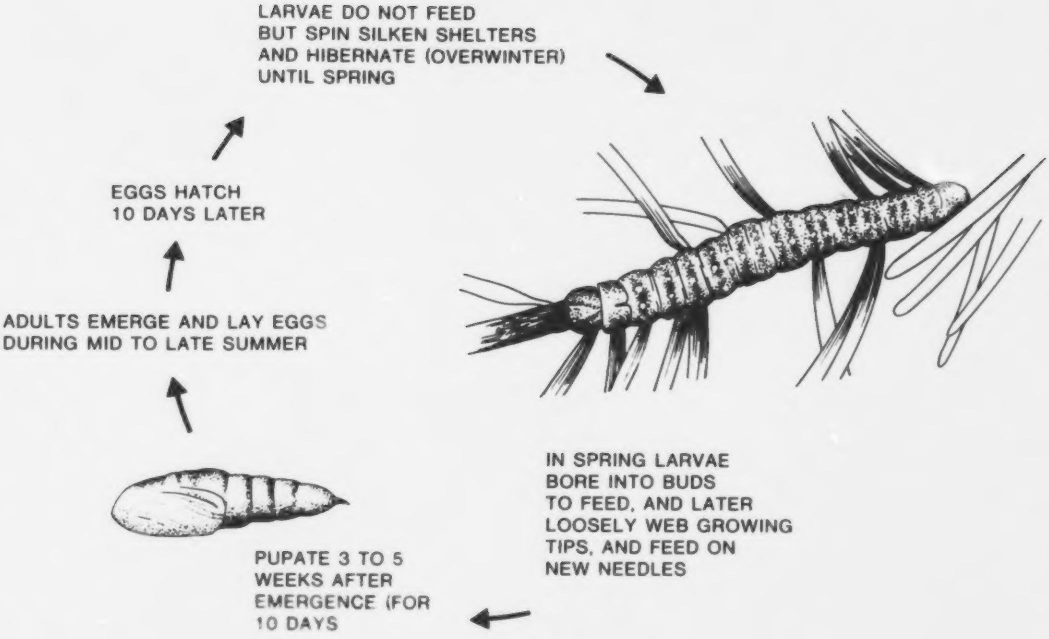
LARVAE DO NOT FEED
BUT SPIN SILKEN SHELTERS
AND HIBERNATE (OVERWINTER)
UNTIL SPRING
EGGS HATCH
10 DAYS LATER
ADULTS EMERGE AND LAY EGGS
DURING MID TO LATE SUMMER
IN SPRING LARVAE
BORE INTO BUDS
TO FEED, AND LATER
LOOSELY WEB GROWING
TIPS, AND FEED ON
NEW NEEDLES
PUPATE 3 TO 5
WEEKS AFTER
EMERGENCE (FOR
10 DAYS

Figure 110. Life history of western spruce budworm (one generation per year).

Figure 111. Adult western spruce budworm (courtesy of Forest Insect and Disease Survey, P.F.C., Victoria, B.C.).

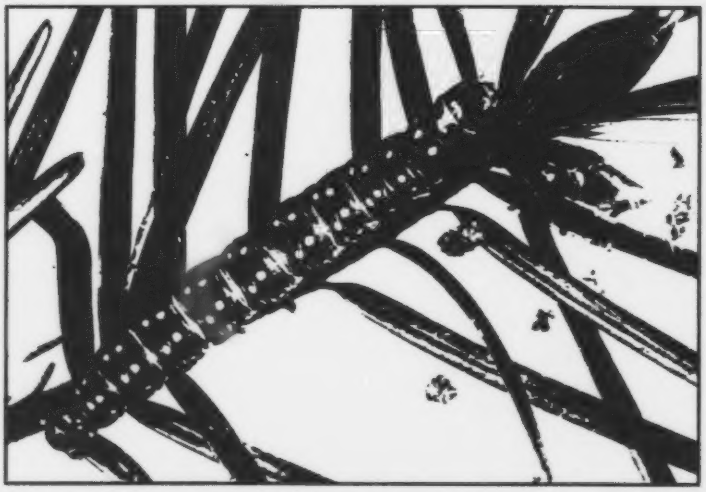

Figure 112. Western spruce budworm larva. Note webbing on right (courtesy of Forest Insect and Disease Survey, P.F.C., Victoria, B.C.).

Western spruce budworm

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Douglas-fir and spruces	1 + 0 2 + 0 Transplants	Spring through early summer	No	Yes	No	Yes

nent ivory-colored spots, emerge and spin long silken threads that aid in their dispersal. They can continue invading nurseries up to their last instars in early July when they pupate (Figure 113). As well, newly planted seedlings in reforestation sites can be attacked in the spring by larvae, acquired in the nursery, which have survived cold storage on stock lifted the preceding winter.

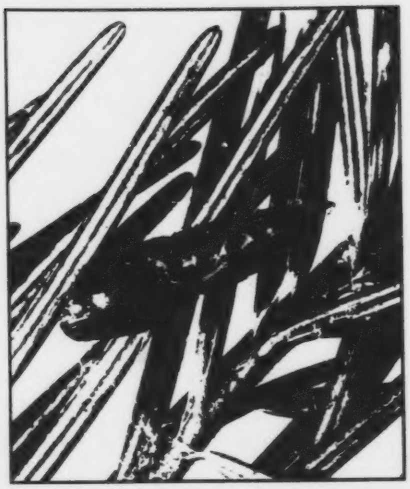

Figure 113. Western spruce budworm pupa (courtesy of Forest Insect and Disease Survey, P.F.C., Victoria, B.C.).

Management

Because of the small size of nursery seedlings and the voracious feeding behaviour of budworm larvae, it is important that nursery workers carefully monitor seedlings in the spring and control larvae that blow onto the stock after they have overwintered in mature trees in and around the nursery site.

Adult moths pose a further threat because they can oviposit on nursery stock, greenhouse structures, or nursery equipment such as styroblocks. The resulting larvae will accompany lifted stock to planting sites or invade newly sown seedlings at the nursery the following year. Pheromone or light traps can be used to monitor adult populations. Significant infestations may require use of a foliar spray to prevent oviposition, applied at the beginning of moth emergence and repeated at 2-week intervals as long as adults are present. This spray works partly as a repellant to moths and, through contact activity, kills moths that alight on foliage to lay eggs.

Selected References

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Unger, L.S. 1986. Spruce budworms in British Columbia. , Can. For., Serv. Pac. For. Cent., For. Pest Leafl. 31. Victoria, B.C. 4 p.

European pine shoot moth

The possibility of the European pine shoot moth, *Rhyacionia buoliana* spreading from the southern coast of British Columbia to the pine forests of the Interior and north coast is of concern. Thus, movement of pines and foliage from the Vancouver Forest Region is regulated under the Plant Protection Act.

Hosts and damage

European pine shoot moth larvae attack most two- and three-needle pines, preferring Mugho and Scots pine over ponderosa and lodgepole pine. Five-needle pines are relatively resistant. The insect is mainly a pest of newly established plantings, parks, gardens, and commercial nurseries. Larvae damage 2-year-old bareroot and container seedlings and 1+0 container stock. Larvae (caterpillars) hatch from eggs laid near buds (Figure 114), feed on needles and later bore into buds and shoots where they overwinter. Consequently, seedling growth is distorted and growth rate reduced. Most nursery stock is too small to sustain successful larval infestation; as a result, many of these larvae die.

Life history (Figure 115)

Adult moths (Figure 116) have a wingspan of 2 cm, orange forewings marked with irregular silvery lines, and gray hindwings. Flying from June to July, they produce one generation annually. Yellowish, disk-shaped eggs are laid near buds. The eggs then hatch and the larvae

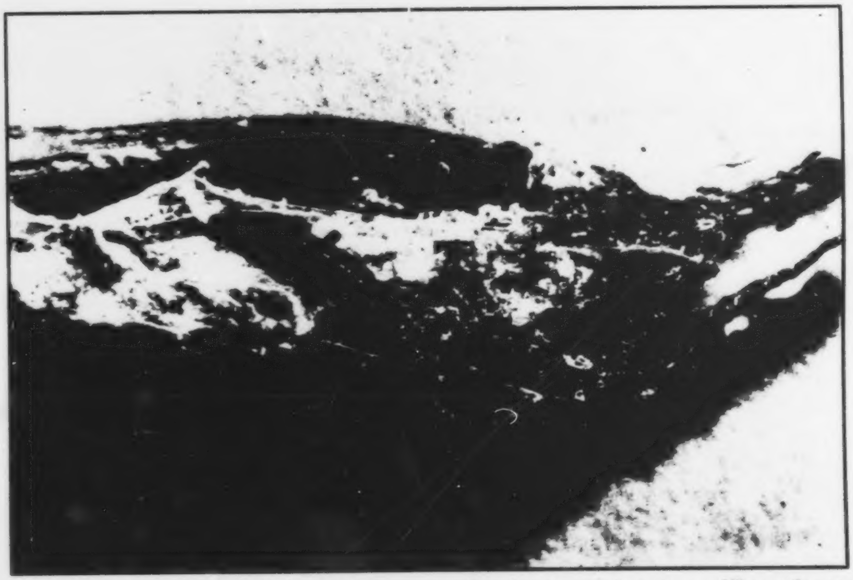

Figure 114. Larva (caterpillar) of the European pine shoot moth (courtesy of Forest Insect and Disease Survey, P.F.C., Victoria, B.C.).

European pine shoot moth

Principal, locally grown hosts	Host age and season when damage appears		Nursery type and location			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All pines, 5-needle pines relatively resistant	1 + 0 2 + 0 Transplants	Late summer through winter	Yes	No	Yes	No

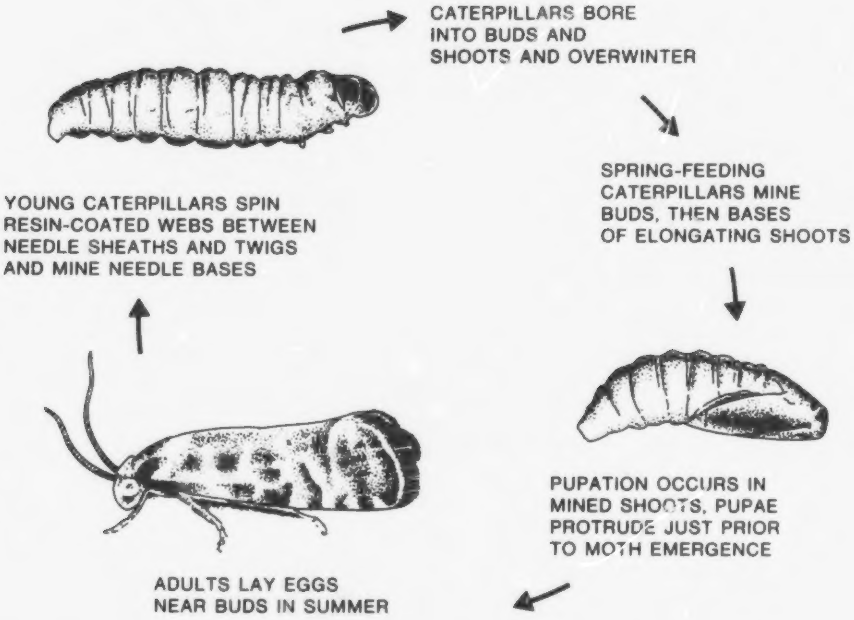
CATERPILLARS BORE INTO BUDS AND SHOOTS AND OVERWINTER
SPRING-FEEDING CATERPILLARS MINE BUDS, THEN BASES OF ELONGATING SHOOTS
PUPATION OCCURS IN MINED SHOOTS, PUPAE PROTRUDE JUST PRIOR TO MOTH EMERGENCE
ADULTS LAY EGGS NEAR BUDS IN SUMMER
YOUNG CATERPILLARS SPIN RESIN-COATED WEBS BETWEEN NEEDLE SHEATHS AND TWIGS AND MINE NEEDLE BASES

Figure 115. Life history of European pine shoot moth (one generation per year).

spin small resin-coated webs between the needle sheath and twig, and mine the base of needles. Later, the larvae bore into buds causing a crust of dried pitch to form and overwinter.

In the spring, these larvae mine other buds and bases of elongating shoots. Here pupae develop (Figure 117), and later protrude from the shoot prior to moth emergence.

Management

Since 1981, a pheromone-trapping program has been used at all nurseries in the quarantine zone. If moths are caught, insecticidal sprays aimed at adult moths, eggs, and young larvae (before they bore into buds) are necessary. So far, only two nurseries have detected moths.

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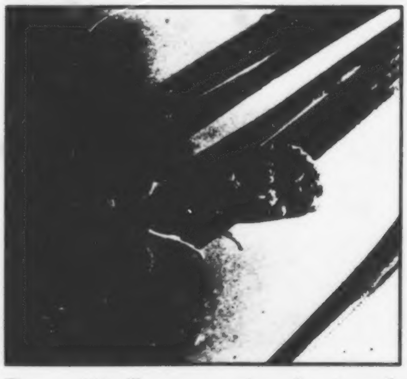

Figure 116. European pine shoot moth (courtesy of Forest Insect and Disease Survey, P.F.C., Victoria, B.C.).

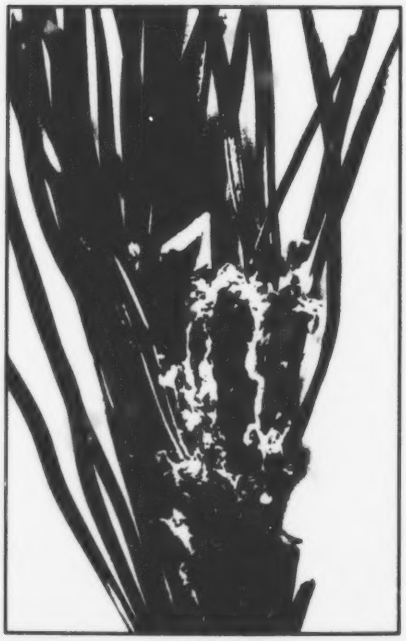

Figure 117. Pupa of the European pine shoot moth (courtesy of Forest Insect and Disease Survey, P.F.C., Victoria, B.C.).

MINOR INSECTS IN BRITISH COLUMBIA FOREST SEEDLING NURSERIES

Insects	Hosts	Type of nursery	Season	Remarks	Reference
EARWIGS Dermaptera	Many	Coastal, container Interior, container	Spring	May sever stems of small seedlings.	Metcalf, C.L. and W.P.Flint. 1962. Destructive and useful insects. Their habits and control. 4th ed., McGraw-Hill, New York, N.Y.
GRASSHOPPERS Orthoptera	Many	Interior, bareroot and container	Spring Summer	Bites seedling stems off at soil line; foliage partially or wholly stripped.	As above.
ORANGE TORTRIX *Argyrotaenia citrana*	Spruces Lodgepole pine Western hemlock	Coastal, bareroot and container	Summer	Incidental, causes minor defoliation; could feed on many seedling hosts.	U.S. For. Serv., Misc. Publ. No. 1339.
THRIPS Thysanoptera	Western red cedar, Lodgepole pine	Coastal, container Interior, container	Summer	Needle malformation and necrosis.	As above.
NEEDLE TIERS *Choristoneura rosaceana* *Archips rosana*	Many	Coastal, container Interior, container	Spring	When seedlings are 2-3 cm tall, larvae web the uppermost needles together.	As for earwigs.

GLOSSARY[5]

Aeciospore - One of several kinds of spores produced by a rust fungus. Formed in and released from a fruiting structure called an aecium (7).

Alternate host - One or the other of the two unlike host plants parasitized by a heteroecious fungus such as a typical rust fungus (7).

Ascomycete - A large group of fungi which are characterized by the free cell formation of spores, usually eight in number, in a saclike structure called an ascus (7).

Ascospore - Sexual spore of an ascomycete fungus, contained in a sac called the ascus (3).

Asexual state or spore - Either a vegetative stage or a reproductive stage in the life cycle of a fungus, in which nuclear fusion is absent and in which reproductive spores are produced by mitosis or simple nuclear division. Synonym: imperfect state (7).

Bait station - Used on nurseries primarily to catch adult root weevils. Consists of a clay drainage tile or plastic pipe about 30cm long, placed horizontally on the soil surface and filled with earwig and weevil bait until the bottom is evenly covered (definition by the authors).

Basidiomycete - A large group of fungi which are characterized by the production of spores, usually four, on a basidium (7).

Basidiospore - The spore produced by the sexual stage of the basidiomycetes (7).

Blight - A general term for a plant disease causing rapid death or dieback (7).

Canker - A definite, relatively localized, necrotic lesion primarily of the bark and cambium (7).

Chlamydospore - A thick-walled asexual resting spore typically formed by many soil-borne fungi (7).

Chlorosis - An abnormal yellowing of the foliage (7).

Chlorotic - Abnormally yellow (7).

Conidium(ia) - Asexual spore of a fungus, typically produced terminally on a specialized hypha termed a conidiophore (7).

Container - See "Styroblock."

Cotyledon - The seed leaf; one in the monocotyledons, two in the dicotyledons (1).

Cull - A seedling that is rejected because it does not meet certain specifications (7).

Decay - The decomposition of plant tissue by fungi and other micro-organisms (7).

Dieback - The progressive dying of stems and branches from the tip downward (7).

Disease - Unfavorable change of the function or form of a plant from normal, caused by a pathogenic agent or unfavorable environment (7).

Endemic - Native to the country or region (7).

Epicotyl - The shoot part of the embryo or seedling above the cotyledon or cotyledons, consisting of an axis and leaf primordia (4).

Epidemic - Pertaining to a disease that has built up rapidly and reached injurious levels (7).

Fallow - Cultivated land allowed to lie idle or unplanted during the growing season (7).

Fumigation - To apply vapor or gas to, especially for the purpose of disinfecting or destroying pests (7).

Fungicide - Chemical that is toxic to fungi (7).

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[5] Numbers following the definitions indicate their sources.

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2. Dobbs, R.C., D.G.W. Edwards, J. Konishi, and D. Wallinger. 1976. Guideline to collecting cones of B.C. conifers. B.C. For. Serv. and Can. For. Serv. Joint Rep. 3.
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8. Province of British Columbia. 1987. Handbook for pesticide applicators and dispensers. 5th ed., Ministry of Environment, Pesticide Control Branch, Victoria, B.C.

Fungus(gi) - An undifferentiated plant lacking chlorophyll and conductive tissues (1).

Gall - A pronounced swelling on a woody plant caused by certain fungi, bacteria, insects, or nematodes (7).

Germ tube - The early growth of mycelium produced by a germinated fungus spore (1).

Hard pines - Pines with needles in clusters of two or three (definition by the authors).

Herbicide - A pesticide used to control or manage weeds (8).

Host - The plant on or in which a pathogen exists (7).

Host range - All hosts that a particular pathogen attacks (7).

Hypha(e) - One of the filamentous threads that make up the fungus body (7).

Hypocotyl - That part of the axis of a developing embryo just below the cotyledons (7).

Infect - To invade and cause a disease (7).

Infest - To be present within an area (or plant or soil) in such numbers as to be a disease hazard (7).

Inoculate - To place a pathogen on or in a host in a position in which it is capable of causing a disease (7).

Inoculum - The spores, mycelium, sclerotia, or other propagules of a pathogen which initially infect a host or crop (7).

Insect - A member of the arthropod class Insecta, characterized by possession of a body divided into three segments, bearing three pairs of legs on the thorax in the adult stage and one pair of segmented antennae on the head (5).

Insecticide - A pesticide used to control or manage insects (8).

Instar - The period or stage between molts in the larva, numbered to designate the various periods: e.g., the first instar is the stage between the egg and first larval molt (5).

Larva(e) - A young insect differing fundamentally in form from the adult, typical of insects that undergo complete metamorphosis, as in the insect orders, Coleoptera, Hymenoptera, and Diptera (5).

Latent infection - An established infection that gives no sign of its presence, remaining viable but inactive (definition by the authors).

Lesion - A defined necrotic area (7).

Metamorphosis - Series of changes through which an insect passes in developing from egg to adult (5).

Mite - A member of the order Acarina in the class Arachnida (the class of arthopods to which spiders belong), characterized by small size and the lack of obvious division of the body into head and thorax (3).

Miticide - A pesticide used to control or manage mites (8).

Mould (also spelled "mold") - Any profuse or woolly fungus growth on damp or decaying matter or on the surface of plant tissue (1).

Mycelium(ia) - A mass of hyphae that forms the vegetative filamentous body of a fungus (7).

Mycorrhiza(e) - A symbiotic association of a fungus with the roots of a plant (1).

Necrosis - Death of plant cells usually resulting in darkening of the tissue (1).

Nematicide - A chemical compound or physical agent that kills or inhibits nematodes (1).

Nematode - Generally microscopic, wormlike animals that live saprophytically in water or soil, or as parasites of plants and animals (1).

Nymph - Young stage of insects having incomplete metamorphosis, as in Hemiptera (5).

Oogonium(ia) - The female sex organ of oomycetes (6).

Oospore (of oomycetes) - The resting spore from a fertilized oosphere (the "egg" of the oogonium); a like structure produced by parthenogenesis (6).

Oviposition - Laying of eggs (3).

Parasite - An organism living on and nourished by another living organism (7).

Parthenogensis - Reproduction without male fertilization (5).

Pathogen - An organism that causes a disease (7).

Pathogenic - Capable of causing a disease (7).

Perfect state - The stage in which the sexual spore stage is produced. Synonym: sexual state (7).

Perithecium(cia) - A globe or flask-shaped fruiting body, produced by certain ascomycete fungi, with an opening or pore (ostiole) through which the ascospores are discharged (3).

Pesticide - Under the British Columbia Pesticide Control Act, any substance or mixture of substances, other than a device, intended for killing, controlling, or managing insects, rodents, fungi, weeds, and other forms of plant or animal life that are considered to be pests (8).

Pheromones - Chemicals produced by insects and other animals to communicate with other members of the same species. Some are used to monitor or control insect populations, but in most cases these are synthetic pheromones (8).

Phycomycete - A group of lower fungi which includes the water moulds (7).

Phytotoxic - A chemical that is toxic to plants (7).

Pitfall trap - A jar or other container buried to its rim in the soil, used to catch beetles and other insects that crawl on the surface of the soil (definition by the authors).

Provenance - The geographical area and environment to which the parent trees are native. The geographical source or place of origin of a given lot of seed or pollen. Frequently synonymous with seed source (2).

Pupa(e) - The intermediate stage between the larva and the adult (5).

Pycnidiospore - An asexual spore or conidium produced within a pycnidium (7).

Pycnidium(ia) - An asexual type of fruiting body, typically flask-shaped, in which asexual spores or conidia are produced (7).

Rot - see "Decay."

Rust - A disease induced by parasitization by one of the rust fungi; masses of orange-colored spores on leaves, fruits, or stems; a rust fungus (3).

Saprophyte - An organism using dead organic material as food (7).

Sclerotium(a) - A firm, frequently rounded multicellular resting structure produced by fungi (7).

Seedlot - An indefinite quantity of seeds having in common species, provenance, year of collection, and handling history; identified by a number for reforestation purposes (2).

Sexual state - The stage in the life cycle of a fungus in which spores are produced after sexual fusion. Synonym: perfect state (7).

Sign - The pathogen or its parts or products seen on the host plant (1).

Sporangium(ia) - A container or case of asexual spores (1).

Spore - The reproductive structure of the fungi and other lower plants (7).

Sporulate - To produce and release spores (7).

Styroblock - A rectangular block, molded from expanded polystyrene beads, with round, tapered cavities and ribs to control root spiraling of seedlings; blocks are available in a variety of sizes (definition by the authors).

Susceptible - Unable to withstand attack by an organism or damage by a non-living agency without serious injury (7).

Symptom - The evidence of disturbance in the normal development and function of a host plant, i.e., chlorosis, necrosis, galls, brooms, stunting, etc. (7).

Systemic - Affecting or distributed throughout the whole plant body (7).

Teliospore - The spore of the rust fungi from which the perfect state of the basidium and basidiospore arise (7).

Urediniospore - One of the many spore stages produced by the rust fungi in their complicated life cycle. These spores are produced in a fruiting body called a uredinium (7).

Uredinium(ia) - One of the many types of fruiting bodies formed by the rusts in their complicated life cycle. Urediniospores are formed in this fruiting body (7).

Wilt - A type of plant disease characterized by the sudden loss of turgor and collapse of the succulent parts of the affected plants (7).

Zoospore - A spore bearing flagella and capable of moving in water (1).

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